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Alternatives to phosphine fumigation of stored grains: The Indian perspective

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Abstract

Out of a total about 10% post-harvest loss of grains, a significant 6% are damaged during their storage. Fumigation of the stored grains is considered indispensable to check this avoidable loss. Methyl bromide (MB), a cheap, broad spectrum fumigant, has to be phased out honouring 'Montreal Protocol'. Phosphine widely used worldwide, is the only fumigant currently used in India, because of its low cost, availability and residue-free treatment. But one serious limitation of use of phosphine is development of resistance in the major stored grain insect-pests. There are several other fumigants like sulfuryl fluoride, propylene oxide, carbonyl sulphide, ethyl formate, hydrogen cyanide and methyl iodide which have been found promising but cost remains a serious factor, especially for a country like that of India. Beside fumigants, use of Modified Atmospheres (MAs) seems to be the best bet for pesticide free organic storage. However, the technology of MAs can be well adapted where cheap sources of nitrogen or carbon dioxide are available and the storage structure is well sealed. Biogas, produced from the cow dung at farm level in many households of Punjab (India) has shown promising results to control the insect-pests in stored grains and pulses without affecting their germination and quality. Ozone, a strong oxidant, has also been successfully tried for control of stored grain insect pests, but its corrosive property towards most of the metals, is a concern. Though many volatile plant oils have proved quite effective to check the stored grain insect-pests but lack of systematic toxicological data has limited their use as practical agents for the safe storage of food grains. In the present scenario, it seems worthwhile to continue to use phosphine as fumigant for the control of stored grain insect-pests with its improved formulations exercising all the precautionary measures, till a new one equally competent is made available. Further, experimentation with other new fumigants should be continued to explore their potential. There is need to undertake further field level trials with biogas in the stored grains.

Key words: Stored grains, insect pests, fumigants, phosphine

The swelling population of India needs to be fed by producing more and protecting more. Protection of food grains is the primary duty of any nation. Unfortunately, the post-harvest losses in India remain static at 10% since decades (Dhuri 2006). That means more production of food grains also lead to its more wastage. Out of this, huge grain loss takes place during its storage which is estimated to be around 6%; the major factor being improper storage resulting from damage by insects, moulds and rats. Higher moisture contents accentuated these losses. The golden principle of 'storing the grain dry' needs to be followed.

Fumigation is considered as quick and effective tool for control of stored grain insect-pests. The concept of 'Zero tolerance of insect-pests in food commodities' has made fumigants further indispensable. However, given to the regulatory concerns and development of resistance, use of conventional fumigants such as phosphine has become very challenging. Therefore, strenuous efforts are being made to find its alternatives. Environmental safety, efficacy and cost shall determine the value of a fumigant. Fumigation registration takes into account any adverse effect of its residues in food and the environment. Since the last 3 decades, several fumigants have been withdrawn or discontinued on the bases of above parameters.

Fumigants can be used: a) as a hygienic measure during storage; b) to provide wholesome food for consumer; and c) as a mandatory requirement in trade and in quarantine (Rajendran 2001). Many fumigants have been withdrawn on the grounds of environmental safety, cost, carcinogenicity and several other factors (Navarro 2006). After phasing out of methyl bromide in view of Montreal Protocol, the only synthetic fumigant, phosphine is being used for protection of stored grains in India. However, apart from methyl bromide and phosphine, the world has seen development of several new fumigants such as sulfuryl fluoride, carbonyl sulphide, propylene oxide, methyl iodide, ozone, ethyl formate and hydrogen cyanide. This article deals with the scope and limitations of both old and new fumigants, with special reference to the Indian scenario.

Phosphine

At present, phosphine (PH_3) is the only fumigant exclusively used in enclosed situation for killing stored gain insect-pests in India. The phase-out of methyl bromide has drastically increased its use not only in quantity, but in variety of stored products other than the food grains such as spices, cocoa beans, dried fruit, nuts and even fresh fruits (Horn *et al.* 2005). Phosphine is available both in solid and gaseous formulations i.e. tablets of aluminium or magnesium phosphide and in cylinders containing carbon dioxide ECO2FUME® or nitrogen FRISIN®. The tablets upon coming in contact with water from the grain moisture releases phosphine gas. Phosphine acts on two enzymes, oxydase cytochrome and catalase (Ducom 2006) which regulate the conditioning of oxygen to enter the mitochondrion. Blocking their action makes it impossible for oxygen to penetrate into the cell leading to formation of super oxides which are the true biocidal agents. The deactivation of the enzymes occurs at low phosphine concentrations, but it proceeds according to the acquisition of resistance. For example, in Australia, the minimum concentration to block the enzymes went, for all species, ranges from 25 ppm in 1990 to more than 100 ppm in 2004. In other countries, 200 ppm has been chosen, like in France, the UK or Australia (Ducom 2005).

Cylinder-based formulations allow a quick gas release and concentrations build up very quickly (Ducom 2006). With a solid formulation, it is necessary to introduce all at once a quantity which takes into account sorption and leaks. With cylinder based formulations, the dosage can be adjusted from time to time to be above the minimum concentration and the total quantity delivered is then lowered. Phosphine can also be produced very quickly and independently of weather conditions with generators using special solid phosphide formulation which can be put into water without exploding. Phosphine is produced almost as quickly as with cylinder-based formulations, without the need to transport the cylinders.

Development of resistance in target insect pests remains an all time serious issue relating to use of phosphine as fumigant. It has developed resistance in a number of pest species (Schlipalius *et al.* 2006; Aurelio *et al.* 2007; Lilford *et al.* 2009; Ahmed *et al.* 2013). Apart from this, the other limitations of use of phosphine are requirement of several days of exposure to achieve the desired level of control. Further, phosphine is known to erode copper and its alloys and hence electrical and electronic items need protection from its exposure. Phosphine is also reactive to some metallic salts which are contained in sensitive items like photographic film and some inorganic pigments. Many deaths have been reported in India where its tablets have been used as suicidal weapon (Garg *et al.* 2009).

Methyl bromide

Methyl bromide (MB) played significant role as a cheap, broad spectrum, effective fumigant with remarkable penetration ability and quick action. But it is known to have detrimental effect on the stratospheric ozone layer. Considering this, it has already been phased out in all the developed countries of the world since the year 2005 and by the end of the year 2015, its use has been banned in the developing countries as well, including India as per the Montreal Protocol, an international treaty signed by 175 countries in 1987. However, quarantine and pre-shipment (QPS) treatments and critical uses where no alternative has yet been available, the ban has been exempted (TEAP 2000). The methyl bromide exemptions, shall, however remain a subject of review in the light of further advancement of research in this area. The scientists are trying to develop the technologies that allow the recovery of methyl bromide to recycle or destroy instead of release it to the atmosphere. Such technologies seem to have some scope to be implemented in North America and Europe though these are complex, expensive and need technical assistance (Novarro 2006). Hence, there may be only limited use of this technology.

Sulfuryl fluoride

Sulfuryl fluoride (SF) is being used as structural fumigant for dry wood termite control since over half a century. It is an inorganic, non-flammable, odourless and colourless gas used to fumigate buildings, transport vehicles, wood, flour mills, food factories, dried fruits, tree nuts and cereal grains (Cox 1997; Bell *et al.* 1999; Navarro 2006). It is produced in USA under the trade names of Vikane (998.8% SF + 0.2% inert materials) and Profume (Novarro 2006) and in China under the trade name Xunmiejin (Guogan *et al*. 1999). Sulfuryl fluoride seems to have the potential of replacing methyl bromide in terms of similar exposure time of 24 hours at normal conditions (Emekci 2010). Moreover, it has some advantages over methyl bromide such as faster diffusion rates in the treated commodities (Novarro 2006). But, the fact that it has the potential of acting as a greenhouse gas, may restrain its use as a fumigant, in future. The fumigant has also been observed as highly toxic to diapausing larvae of codling moth, *Cydia pomonella* in stored walnuts (Zettler *et al.* 1999).

Insect eggs are the most tolerant stage to the fumigation action of sulfuryl fluoride which is also a limiting factor. To overcome the failure in the control of egg stages of pests, use of sulfuryl fluoride in combination with other fumigants such as hydrogen cyanide (HCN), CO_2, phosphine or heat has been proposed. In Germany, a combination of 2 g m^{-3} of HCN and about 30 g m^{-3} of sulfuryl fluoride provide successful control of the pests within 40 hours. By combining sulfuryl fluoride with heat could provide complete control of egg stages of main pests of stored products. Further, sulfuryl fluoride can also be applied under reduced pressure so that the exposure period can be drastically reduced (Zettler and Arthur 2000).

Propylene oxide

Propylene oxide (PPO) is a colourless, flammable liquid commonly used in the chemical industry as an intermediate industrial product besides its use as a food emulsifier, surfactant, cosmetic and starch modifier. Under normal temperature and pressure, it has relatively low boiling point (35 °C) and a noticeable ether odour (Weast *et al.* 1986). It is a safe fumigant for use on food and has been registered and used in USA since 1984 as a sterilant for commodities such as dry and shelled walnut, spices, cocoa powder and nutmeats (Griffith 1999). Since PPO is flammable from 3 to 37% in air, it has to be used under low pressures or in CO_2-enriched atmospheres to avoid flammability (Isikber *et al*. 2006). Therefore, PPO with low pressure can replace methyl bromide at commercial level in quarantine and pre-shipment (QPS) conditions where low pressure treatments are technically and economically available and feasible. In contrast to methyl bromide, PPO is not an ozone depletor and degrades into nontoxic, biodegradable, propylene glycol in the soil and in human stomach (Emekci 2010).

Carbonyl sulphide

Carbonyl sulphide (COS), a major sulphur compound naturally present in the atmosphere at 0.5 (± 0.05) ppb, is colourless gas present in foodstuffs such as cheese and prepared vegetables of the cabbage family (Wright 2000). Its traces are naturally found in grains and seeds in the range of 0.05-0.1 mg/kg (Wright 2000; Novarro 2006). As per laboratory findings, COS is effective on a wide range of stored-product pests in all stages, including mites, at concentrations from 10 to 40 g/m^3, at exposure time 1 to 5 days at temperature ≥ 5 °C (Desmarchelier 1994). COS as a fumigant for fumigation of durable commodities and structures was trademarked in Australia as COSMIC-™ since 1992. BOC Limited has an agreement with CSIRO for its manufacture and worldwide distribution (Ducom 2006). Studies in Australia, Germany and the USA revealed that egg stage was highly tolerant to the fumigant; the effective exposure period, however, was half that of phosphine at temperatures above 5 °C (Rajendran 2001). There was no adverse effect on the quality of bread, noodles or sponge cake (wheat), the malting and brewing characteristics of barley, nor a significant effect on germination or plumule length (Desmarchelier *et al*. 1998; Wright 2003). However, there are contradictory reports in the literature on negative effects of COS on germination of cereals except sorghum and barley, off odours in walnuts, in milled rice, and colour change in soybeans (Navarro 2006).

Ethyl formate

Ethyl formate (EF), a volatile solvent, highly flammable, boils at 55 °C and vaporizes rapidly at normal temperature (Emekci 2010) that occurs naturally in a variety of products including beef, cheese, rice, grapes and wine. It is generally recognized as a safe compound (Desmarchelier 1994). It is used as flavouring agent in the food industry (Rajendran 2001; Novarro 2006). It is known to break down into naturally occurring products i.e. formic acid and ethanol. The mode of action seems to be the inhibition of Cytochrome C Oxidase by the formic acid resulting of the hydrolysis of EF (Haritos and Dojchinov 2003).

In India, extensive laboratory tests against insect-pests of food commodities and field trials on cereals, spices, pulses, dry fruits and oilcakes have been carried out on the fumigant. Effective commodity dosage ranged from 300 to 400 g m^{-3} with 72 hour exposure period (Rajendran 2001). EF is registered in Australia for disinfestation of dried fruits and is particularly used for dried sultanas where it is added as a liquid to packages of fruit before they are sealed (Annis and Graver 2000).

To overcome flammability of EF, BOC Limited has developed and registered Vapromate® (for use in Australia since 2005), a cylinderised formulation of 16.7% (w/w) ethyl formate in liquid carbon dioxide (Ducom 2006). It is a new cereal grain, stored product and fresh produce fumigant for application by pressurised cylinders. CO_2 acts in two ways: the mixture in this proportion is non-flammable and it has a synergetic effect; its action is rapid, in a range of 4 to 24 hours. Further, it is a safe fumigant since TLV is 100 ppm for EF and 5000 for CO_2. In case of phosphine-resistant field strain of *Ryzopertha domonica* (F);

laboratory strains of *Tribolium castaneum* (Herbst) and *S. oryzae*, a single dose of 450 g m^{-3} of Vapromate was found to be sufficient to obtain high level of mortality (> 99%) of all stages of *T. castaneum* and *R. dominica* (Haritos *et al*. 2006). Forced flow application of ethyl formate and CO_2 vapours through the grains by means of a pump at a flow rate of 6 l per minute, not only provides more even distribution of the fumigant but also causes very high level of mortality of *S. oryzae* and *T. castaneum* mixed stage cultures (Haritos *et al*. 2006). EF when used with methyl isothiocyanate (MITC), a soil fumigant, could significantly reduce the dosage of EF to below the flammable level. A mixture of EF and MITC (95% EF + 5% MITC) has been patented under the name of GLO2 (Ren *et al.* 2008). GLO2 has been found effective against all stages of the major stored grain insect pests. It is fast acting (less than 24 hours) and requires a short withholding period, about 8 days, but much less with aeration.

Hydrogen cyanide

Hydrogen cyanide (HCN) is a colourless liquid with smell of bitter almonds, flammable and lighter than air. Currently, it is registered only in India, New Zealand and with severe restrictions in Germany (Navarro 2006). Earlier HCN has been used to fumigate mills in various countries (France, Germany, Switzerland) (Rambeau *et al*. 2001). HCN can be used for fumigation of many dry foodstuffs, grains and seeds.

Due to high degree of sorption at atmospheric pressure, it does not have the quick effective penetration that methyl bromide has (Emekci 2010). It is easily dissolved in water and thus will bind with moisture and can be difficult to ventilate. Although HCN is strongly sorbed by many materials, this action is usually reversible when they dry, and, given time, all the fumigant vapours are desorbed (Navarro 2006). Further, the high dermal toxicity of the gas makes it hazardous to applicators.

Carbon disulphide

Carbon disulphide (CS_2) is an old fumigant used at the farm level in some parts of Australia and to a limited extent in China (TEAP 2000). Though, the fumigant has only small effect on germination, but residues of carbon disulphide persist in treated commodities for a longer period than that of other fumigants (Haritos *et al*. 1999). The reduction in baking quality of wheat treated with this fumigant was shown by Calderon *et al.* (1970). Some of the limitations of the fumigant include high flammability, long exposure period, persistence in the treated commodity, lack of residue limits set by Codex Alimentarius and high human toxicity (Navarro 2006).

Methyl iodide

Methyl iodide (MI) was patented as pre-plant soil fumigant for the control of broad range of organisms including nematodes, fungi and weeds (Grech *et al*. 1996). The patent was subsequently expanded to include structural fumigation against termites and wood rotting fungi (Ohr *et al*. 1998). Potential of MI as a fumigant for post-harvest pest control has been known since about 77 years (Lindgren 1938). But its development could not be pursued in favour of less-expensive methyl bromide. MI is most toxic to eggs and least toxic to adults of *Sitophilus granarius*, *Sitophilus zeamais* Motschulsky, *Tribolium confusum*, and *Plodia interpuntella* (Goto *et al*. 2004). Though, MI is considered as a carcinogenic compound, the US Environmental Protection Agency (EPA) has registered it as a soil fumigant since 2007 (EPA 2009).

Ethane dinitrile/Cyanogen

Ethane dinitrile (EDN), also known as cyanogen (C_2N_2) is a broad spectrum fumigant since it can be used against soil insect pests, weed seeds, nematodes and fungi. It is a colourless gas with an almond like odour and is environmentally safe. The threshold limit value (TLV) of 10 ppm (v/v) compares favourably with that of both methyl bromide (5 ppm) and phosphine (0.3 ppm). It is highly toxic (much more toxic than methyl bromide) to stored product insects and is fast acting (except *Sitophilus* sp.) (Docom 2006) with good penetration capability through the grain mass and it desorbs quickly. Germination of seeds is affected due to phytotoxic properties of EDN.

EDN has great potential for space and flour/rice mills fumigations (Navarro 2006). CSIRO holds patent for use of EDN as a fumigant in the major worldwide markets (Emekci 2010). BOC Limited has signed an exclusive global license agreement with CSIRO for EDN as a soil, timber fumigant and grain sterilant. It is marketed under the trade name Sterigas 1000 Fumigant in Australia (Ryan *et al*. 2006).

Biogas

Biogas, containing about 35% carbon dioxide and rest mainly the methane, primarily produced from cow dung to be used as cooking gas, can also be used to control the stored grain insect pests at farm level. In India, detailed experimentation has been done on this aspect. The killing action is because of the carbon dioxide in the biogas. Though carbon dioxide has been found very effective against the stored grain insect-pests, but its cost and transportation to the site of actual use did not make it viable alternative. One major advantage with biogas is that it is to be used just from the site of production within the farm.

Simply we need some pipes and arrangement to divert it through the air tight grain storage structures as and when needed. This makes it very cheap and convenient to use.

Considerable work has been done in India and China to prove the applicability of biogas as stored grain insect control agent. Pioneering research work on biogas was done in Punjab state of India by Singh and co workers in early 1990's where they reported that it can be used in airtight metal or PVC bins to check infestation by major stored grain insect pests for about 3 months with just one exposure of 6 days (Singh *et al.* 1994). Continued research (Sharma *et al*. 2006) also revealed control of the pulse beetle, *Callosobruchus maculatus* (Fab.) resulting in 100% mortality of both egg and adult stages of the beetle. On-farm trials by passing biogas from the plant through the stored wheat up to 10 quintals, showed success of the technology in ensuring insect-free wheat (Chhuneja *et al*. 1998). The biogas did not affect germination or quality of the wheat.

The optimum biogas flow rate required to remove the oxygen from an empty container and partially grain filled container was found to be 40 ml per minute sustained up to a time leading to an equivalent of three times the volume of the grain container. Using these fumigation conditions 100% adult mortality was observed in *Tribolium castaneum* and *Rhizopertha dominica* within 24 hours and *S. oryzae* within 48 hours (Chanakya *et al.* 2015).

Ozone

Ozone (O_3), a powerful oxidant and a known sterilant, had great potential to be used as insect control agent and inhibitor of mould spore development in the stored grain at levels less than 45 ppm (Rajendran 2001; Navarro 2006; Pimentel *et al*. 2009; Tiwari *et al.* 2010; McDonough *et al*. 2011). Ozone can be readily generated from atmospheric oxygen on the treatment sites and is safe to the environment. However, being highly unstable, it quickly breaks down to the molecular oxygen. But, a major disadvantage with ozone is its corrosive property towards most of the metals (Mason *et al*. 1999). This has, therefore, necessitated a special ozone air delivery and return system for an effective ozonation treatment of the storage facility (Campabadal *et al*. 2007). Ozonation experiments yielded 100% mortality for *Sitophilus zeamais* and *Tribolium castaneum*, placed at 0.6 m below the popcorn grain surface (Campabadal *et al*. 2007). Research on ozone treatments to kill stored product insects, including the maize weevil *Sitophilus zeamais*, the rice weevil *Sitophilus oryzae*, the red flour beetle *Tribolium castaneum*, the confused flour beetle *Tribolium confusum*, the lesser grain borer *Rhyzopertha dominica*, the Indian meal moth *Plodia interpunctella* and the Mediterranean flour moth *Ephestia kuehniella* (Kells *et al.* 2001; Leesch 2003; Athanassiou *et al.* 2008; Isikber and Oztekin 2009; Geovana *et al.* 2015) is being undertaken in different parts of the globe.

Modified Atmospheres

Use of Modified Atmospheres (MAs), rich in carbon dioxide and low in oxygen, dates back to ancient times when Egyptians practiced hermetic storage of grains (White and Leesch 1996). Presently, importance of MAs has been enhanced given to the demand for pesticide-free organic food. Terms used in reference to MA storage for control of storage insect pests or for preservation of food have also appeared in the literature as CA (Controlled atmosphere), as sealed storage, or atmospheres used at high or low pressures to define the same method of treatment but using different means (Navarro 2006). Technology of MAs can be well adapted where cheap sources of nitrogen or carbon dioxide are available and the storage structure is well sealed (Rajendran 2001). Till now, MAs composed of either CO_2, N_2 or inert gases have classically been used in different parts of the world for the fumigation of a variety of commodities including grains, pulses, tree nuts, dried fruits, coffee and cocoa beans, spices, medicinal herbs, geophytic bulbs and historic artifacts (Adler *et al*. 2000; Cheng *et al.* 2013).

Low-oxygen atmosphere generated on-site from air through pressure-swing absorption and subsequent filtration through a carbon molecular sieve or through membrane systems or from locally available liquid nitrogen sources has been exploited for disinfesting and storage of food grains in Germany and Australia. Carbon dioxide-rich atmosphere has been found suitable for the protection of dried fruits in Israel and Turkey and for treating grain elevators in Canada (Donahaye *et al* 19984 Ferizli and Emekci 2000; Emekci *et al*. 2007).

Carbon dioxide treatment requires a longer exposure period of 10 days or more; this drawback can, however, be overcome in combination with positive pressure or elevated temperatures which increases performance of MAs. Significant reduction in exposure time to a few hours can be obtained with the use of high carbon dioxide under high pressures ranging between 10-37 bars (Emekci 2010). Eggs, especially in early stages of development were known to be less sensitive to high pressure carbon dioxide treatments than other stages (Adler *et al* 2000; Navarro 2006). Increase in temperature also helps MAs to decrease the lethal exposure time significantly (Donahaye *et al*.

1994).

Hashem *et al*. (2014) studied the susceptibility of the different life stages of the Indian meal moth *Plodia interpuntella* and almond moth *Ephestia cautella* to MAs containing 40, 60 and 80% CO_2 in air at 27 °C. They showed that five days were adequate to kill all eggs and pupae of the two moths under all these MAs. Exposure time needed to be extended to 6 and 7 days at 80% CO_2 to obtain complete mortality of larva of *Ephestia cautella* and *Plodia interpuntella*, respectively. Hashem *et al.* (2014) studies showed that no adults were produced from 4th instar larva of *Sitotroga cereallela* treated with MAs after a 264 h (11 day) exposure for 25% CO_2, 240 h (10 day) for 40% CO_2 and only 168 h (7 day) for 60% CO_2 .

Volatile plant oils as fumigants

Though plant products are known to be mixed with stored grains to ward off insect pests since centuries ago but application of plant oils as fumigants in the protection of stored products is in its infancy (Cox 2002). There is enough literature on the fumigant action of different volatile essential oils of botanical origin to control stored grain insect pests (Shaaya *et al*. 1997; Tunc *et al.* 2000; Weaver and Subramanyam 2000; Rajendran and Muralidharan 2005; Isikber *et al.* 2008; Korunic *et al.* 2008; Rajendran and Sriranjini 2008). Unfortunately, standard test methods applicable for fumigants have not always been followed in the assays (Rajendran 2001). Perhaps, mortality of insects exposed to plant products has been assessed too early. The time taken to express mortality response by the insect treated with fumigants is known to vary between compounds and between the doses of a particular chemical. Besides, data on the toxicity of plant sources against mixed -age cultures containing all developmental stages of stored product insects are lacking (Rajendran 2001).

Most of the research with plant oils as fumigant was carried out in empty fumigation chambers and thus may not reflect the actual fumigation situations where penetration of the plant extracts into deep layers fails, due to strong absorption by the commodity (Emekci 2010). Moreover, aromatic scents of the essential oils permit them only to be applied in empty premises or to the commodities such as seeds where the scent of the volatile essential oil would not present a restriction after the treatment. Another important constraint for the use of botanical extracts is that such alternatives of plant origin also need toxicological and safety data for registration for use as fumigant (Navarro 2006).

Conclusions

Methyl bromide (MB), a cheap, broad spectrum fumigant with remarkable penetration ability and quick action that has been phased out honouring ‘Montreal Protocol’ is yet to find an equally competent alternative. This is both a challenge and urgent necessity. Phosphine is widely used worldwide, and is the only fumigant currently used in India, because of its low cost, availability and residue-free treatment. But limitation of use of phosphine is development of resistance in the major stored grain insect pests, the world over. There are several other alternative fumigants which are location/situation specific, but cost remains a serious factor, especially for country like India. One such alternative is sulfuryl fluoride which has been found quite promising to fumigate buildings, transport vehicles, wood, flour mills, food factories, dried fruits, tree nuts and cereal grains is marketed in USA (Vikane; Profume) and China (Xunmiejin). But, the fact that it has the potential of acting as a greenhouse gas, may restrain its use as a fumigant, in future.

Propylene oxide, though a safe fumigant for use on food and has been registered and used in USA since 1984 as a sterilant for commodities such as dry and shelled walnut, spices, cocoa powder and nutmeats, is flammable and has to be used under low pressures or in CO_2-enriched atmospheres to avoid flammability. Carbonyl sulphide, as a fumigant for durable commodities and structures was trademarked in Australia as COSMIC-™ since 1992. However, there are contradictory reports in the literature relating to negative effects of carbonyl sulphide on germination of cereals except sorghum and barley, off odours in walnuts, in milled rice, and colour change in soybeans.

Ethyl formate, quite effective for dried fruits and several other stored products, is registered in Australia since 2005 (Vapromate®). To overcome its flammability a cylinderised formulation of 16.7% (w/w) ethyl formate) in liquid carbon dioxide has been developed. Hydrogen cyanide (HCN) is registered in India, New Zealand and Germany (Navarro 2006), can be used for fumigation of dry foodstuffs, grains and seeds. But, due to high degree of sorption at atmospheric pressure, it does not have the quick effective penetration as that of methyl bromide. But high dermal toxicity of the gas makes it hazardous to applicators. Methyl iodide, though recommended by US EPA as soil fumigant since 2007; but there is a question mark on its acceptability because of having carcinogenic effect. `

Though efficacy of various plant oils as fumigant, is amply on record, but lack of systematic toxicological data utilizing standard techniques does not reflect any worthwhile future for application of the same as successful agents to control stored grain insect-pests. Use of Modified Atmospheres (MAs) seems to be the best bet for pesticide-free organic storage but the technology of MAs can be well adapted where cheap sources of nitrogen or carbon dioxide are available and the storage structure is well sealed. This does not appears to be very practical for developing or under-developed countries, particularly at the farm/ farmers' level. There is a better option for countries like India if source of bio-gas is available at the farm level in the form of biogas plant wherein the gas is produced from the cow dung. Ozone (O_3), a powerful oxidant and a known sterilant, also has a great potential to be used as insect control agent and inhibitor of mould spore development. However, being highly unstable, it quickly breaks down to the molecular oxygen. Further, a major disadvantage with ozone is its corrosive property towards most of the metals. This has, therefore, necessitated a special ozone air delivery and return system for an effective ozonation treatment of the storage facility.

Given to the kind of storage facilities in India, at present phosphine in tablet form is the only fumigation technique adopted for disinfestations of godowns and even at the farm level farmers are using it to save their stored grains from the damage by insect-pests. One way to increase the efficacy of phosphine could be to use it in cylinder-based formulations with or without carbon dioxide or generators producing phosphine by pouring a granular form of aluminium or magnesium phosphide in water. Though it may not be very appropriate to use CO_2 given to the filling and transportation of CO_2 cylinders but the farm houses where bio-gas plants are installed, use of biogas will both be economical and convenient. Though some work has been done in this direction, more efforts are needed to show its practicability as a cheap and convenient way of saving the stored grains from the attack of stored grain insect-pests at the farm level storage. This could be a good substitutes in all those farm houses where bio-gas plants are installed.

References

Adler C, Corinth HG and Reichmuth C 2000. Modified atmospheres. In: Subramanyam B and Hagstrum DW (Eds.) *Alternatives to Pesticides in Stored Product IPM*. pp 105-146. Kluwer Academic Publishers, MA, USA.

Ahmad A, Ahmed M, Mehmood NQ, Muhammad A and Arif S 2013. Monitoring of resistance against phosphine in stored grain insect pests in Sindh. *Middle -East J Sci Res* **6**: 1501-1507.

Annis PC and Graver JE 2000. Ethyl formate – a fumigant with potential for rapid action. *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 70-73. Florida, USA.

Athanassiou CG, Milonas DN and Saitanis CJ 2008. Insecticidal effect of ozone against *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae), *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Tribolium confusum* Jacquelin Du Val (Coleoptera: Tenebrionidae): influence of commodity. *Proc of the 8th Int Conf on Cont Atm and Fumigation in Stored Products*. pp 61-71. Chengdu, China.

Aurelio M, Pimentel G, FaroniLeda RDA, Totola MR and Guedes NRC 2007. Phosphine resistance, respiration rate and fitness consequences in stored-product insects. *Pest Mgmt Sci* **63**: 876–881.

Bell CH, Savvidou N and Smith TJW 1999. The toxicity of sulfuryl fluoride (Vikane) to eggs of insect pests of flourmills. *Proc of the 7th Int Working Conf on Stored Prod Prot.* pp 345-350. China.

Calderon M, Navarro S and Lindner Z 1970. Effect of common fumigants on the baking quality of wheat. *Cereal Chemistry* **47**: 422-428.

Campabadal CA, Maier DE, Woloshuk CP and Mason L 2007. Ozonation as non-chemical stored product protection technology. *Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 93 -4 .San Diego, California Florida, USA.

Chanakya HN, Parvathi C and Khuntia HK 2015. The efficacy of biogas to protect stored grains from insect pests. *Carb Sci Tech* **7**: 42-52.

Cheng WN, Lei JX, Ahn JE, Wang Y, Lei C and Zhu-Salzman K 2013. CO_2 enhances effects of hypoxia on mortality, development and gene expression in cowpea bruchid, *Callosobruchus maculatus*. *J Stored Prod Res* 59: 1160-1168.

Chhuneja PK, Thapar VK, Singh G and Sethi PS 1998. *Use of biogas for the control of stored grain insect pests at farm level*. Dept. of Processing & Agril. Structures, Punjab Agric. Univ., Ludhiana, p. 43.

Cox C 1997. Sulfuryl Fluoride. *J of Pest Reform* **17**:17-20.

Cox PD 2002. Potential for using semiochemicals to protect stored products from insect infestation - A review. *J Stored Prod Res* **40:** 1-25.

Desmarchelier JM 1994. Carbonyl sulphide as a fumigant for control of insects and mites. *Proc of the 6th Int Working Conf on Stored Prod Prot.* pp 78-82. Australia.

Desmarchelier JM, Allen SE, Ren YL, Moss R and Vu LT 1998. Commercial-scale Trials on the Application of Ethyl Formate, Carbonyl Sulphide and Carbon disulphide to Wheat. CSIRO Entomology, Technical Report No. 75.

Dhuri AV 2006. Fumicover™ An effort in reducing losses in stored grains at farm Levels. *Proc of the 9th Int Working Conf on Stored Prod Prot.* pp 612-617. Brazil.

Donahaye E, Navarro S and Rindner M 1994. The influence of temperature on the sensitivity of two nitidulid beetles to low oxygen concentrations. *Proc of the 6th Int Working Conf on Stored Prod Prot.* pp 88-90. U.K.

Ducom P 2005. The issue of phosphine fumigation. *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions* .San Diego, California.

Ducom P 2006. The return of the fumigants. *Proc of the 9th Int Working Conf on Stored Prod Prot.* pp 510-516. Brazil.

Emekci M 2010. Quo vadis the fumigants? *Proc of the 10th Int Working Conf on Stored Prod Prot.* pp 303-313. Portugal.

Emekci M, Ferizli AG, Tutuncu S and Navarro S 2007. The Applicability Of Controlled Atmospheres As An Alternative To Methyl Bromide Fumigation Of Dried Fruits In Turkey. *Proc of the Int Conf on Cont Atm and Fumigation in Stored Products*. pp 159-166. Australia.

EPA 2009. Extension of Conditional Registration of Iodomethane (MethylIodide), Environmental Protection Agency *http://www.epa.gov/pesticides/factsheets/iodomethane_fs.htm.*

Ferizli AG and Emekci M 2000. Carbon dioxide fumigation as a methyl bromide alternative for the dried fig industry, *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions* pp. 81. Orlando, Florida.

Garg S, Chanana A, Tejpaul HR and Gargi J 2009. Fatal period in murder-suicide celphos (aluminium phoshide) poisoning. *J of Punjab Acad of Forensic Medicine & Toxicology* **9**: 92-95.

Geovana DS, Karim CP and Vildes MS 2015. Reduction in residues of deltamethrin and fenitrothion on stored wheat grains by ozone gas. *J Stored Prod Res* **61**: 65-69.

Goto M, Ogawa N, Naito H and Soma Y 2004. Susceptibility of four stored grain insects to methyl iodide. *Res Bull of the Plant Prot Services Japan* **40**: 1-6.

Grech NM, Ohr HD and Sims JJ 1996. Methyl iodide as a soil fumigant. U.S. Patent, 5518692.

Griffith T 1999. Propylene oxide, a registered fumigant, a proven insecticide. *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 71.San Diego, California.

Guogan X, Zhongmei C, Zhao S and Nengzhi Q 1999. The development of sulfuryl fluoride (SO_2F_2), in China –a brief introduction. *Proc of the 7th Int Working Conf on Stored Prod Prot.* pp 562-566. China.

Haritos VS and Dojchinov G 2003. Cytochrome c oxidase inhibition in the rice weevil *Sitophilus oryzae* (L.) by formate, the toxic metabolite of volatile alkyl formates Comp. *Biochem Physiol C Toxicol Pharmacol*. **136**: 135-143.

Haritos VS and Dojchinov G 2006. Improved efficacy of ethyl formate against stored grain insects by combination with carbon dioxide in a ‘dynamic’ application. *Pest Mngmt Sci* **62**: 325– 333.

Haritos VS Damcevski KA and Dojchinov G 2006. Improved efficacy of ethyl formate against stored grain insects by combination with carbon dioxide in a ‘dynamic’ application. *Pest Mngmt Sci* **62**: 325– 333.

Haritos VS, Ren YL and Desmerchelier JM 1999. Regulatory toxicology of alternative fumigants. *Proc of the 7th Int Working Conf on Stored Prod Prot.* pp 356-363. China.

Hashem MY, Ahmed SS, El-Mohandes MA, Hussain AE and Ghazy SM 2014. Comparative effectiveness of different modified atmospheres enriched with carbon dioxide and nitrogen on larval instars of almond moth *Ephestia cautella*. *J. Stored Prod Res* **59**: 314-19.

Hashem MY, Risha EM, El-Sherif SI and Ahmed SS 2012. The effect of modified atmospheres, an alternative to methyl bromide, on the susceptibility of immature stages of angoumois grain moth *Sitotroga cerealella* (Olivier) (Lepidoptera:Gelechiidae). *J Stored Prod Res* **50**: 57-61.

Horn F, Horn P and Sullivan J 2005. Current practice in fresh fruit fumigation with phosphine in chile. *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 12-19. San Diego, California.

Isikber AA and Oztekin S 2009. Comparison of susceptibility of two stored product insects, *Ephestia kuehniella* Zeller and *Tribolium confusum* du Val to gaseous ozone. *J Stored Prod Res* **45**:159-164.

Isikber AA, Alma MH, Kanat M and Karci A 2008. Fumigant toxicity of essential oils from *Laurus nobilis* and *Rosmarinus officinalis* against all life stages of *Tribolium confusum*. *Phytoparasitica* **34**: 167-177.

Isikber AA, Navarro S, Finkelman S, Rindner M and Dias R 2006. Propylene oxide as a potential quarantine fumigant for insect disinfestation of nuts. *Proc of the 9th Int Working Conf on Stored Prod Prot.* pp 630-634. Brazil.

Jayaram M and Majumder SK 1984. Ethyl formate as a safe general fumigant. *Proc of the Int Conf on Cont Atm and Fumigation in grain storages*. pp. 369-393, Australia.

Kells SA, Mason LJ, Maier DE and Woloshuk CP 2001. Efficacy and fumigation characteristics of ozone in stored maize. *J Stored Prod Res* **37**: 371-382.

Korunic Z, Rozman V and Kalinovic I 2008. The Potential Use of Natural Essential Oils in the fumigation of stored agricultural products *Proc of the 8th Int Conf on Cont Atm and Fumigation in Stored Products*. pp 511-519. China.

Leesch JG 2003. The mortality of stored product insects following exposure to gaseous ozone at high concentrations. *Proc of the 8th Int Working Conf on Stored Prod Prot.* pp 827-831. Oxon, UK.

Lilford K, Fulford GR, Schlipalius D and Ridley A 2009. Fumigation of stored grain insects -a two locus model of phosphine resistance. In: *18th World IMACS/ MODSIM Congress*.pp. 540-546. Cairns, Australia.

Lindgren DL 1938. Methyl iodide as a fumigant. *J of Econ Ent* **31**: 320.

Mason LJ, Strait CA, Woloshuk CP and Maier DE 1999. Controlling stored grain insects with ozone fumigation. *Proc of the 7th Int Working Conf on Stored Prod Prot.* pp 536-547. China.

Mason LJ, Woloshuk CP and Maier DE 1997. Efficacy of ozone to control insects,molds and mycotoxins. *Proc of the Int Conf on Cont Atm and Fumigation in Stored Products*. pp 665-670. Cyprus Printer Ltd, Nicosia.

McDonough MX, Campabadal CA, Mason LJ, Maier DE, Denvir A and Woloshuk CP 2011. Ozone application in a modified screw conveyor to treat grain for insect pests, fungal contaminants and mycotoxins. *J Stored Prod Res* **47**: 249-254.

Navarro S 2006. New global challenges to the use of gaseous treatments in stored products. *Proc of the 9th Int Working Conf on Stored Prod Prot.* pp 495-509, Brazil.

Ohr HD, Grech NM and Sims JJ 1998. Methyl iodide as a fumigant. U.S. Patent, 5753183.

Pimentel MAG, Faroni LRD, Guedes RNC, Sousa AH and Totola MR 2009. Phosphine resistance in Brazilian populations of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). *J Stored Prod Res* 45: 71-74.

Rajendran S 2001. Alternatives to methyl bromide as fumigant for stored food commodities. *Pesticide Outlook* **12**: 249-253.

Rajendran S and Muralidharan N 2005. Effectiveness of allyl acetate as a fumigant against five stored grain beetle pests. *Pest Manag Sci* **61**: 97–101.

Rajendran S and Sriranjini V 2008. Plant products as fumigants for stored-product insect control. *J Stored Prod Res* **44**: 126-135.

Rambeau M, Benitez D, Dupuis S and Ducom P 2001. Hydrogen cyanide as an immediate alternative to methyl bromide for structural fumigations. *Proc. of the Int Conf on Cont Atm and Fumigation in Stored Products*. pp 101-111. CA, U.S.A.

Ren Y, Emmeri T, Mahon D and Graver JE 2008. Ethyl formate reformulated a potential fumigant for the grain industry. *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 98-105. Florida, USA.

Ryan R, Martin P, Haines N, Reddi R, Beven D and Harvey A 2006. Sterigas™ & Cosmic™: update on proposed new fumigants. *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 138-142. Florida, USA.

Schlipalius DI, Collins PJ, Mau Y and Ebert PR 2006. New tools for management of phosphine resistance. *Outlooks on Pest Mgmt* **17**: 52–56.

Shaaya E, Kostjukovski M, Eilberg J and Sukprakarn C 1997. Plant oils as fumigants and contact insecticides for the control of stored-product insects. *J Stored Prod Res* **33**: 7-15.

Sharma DK, Singh Jasbir, Thapar VK, Paul Shashi and Singh G 2006. Efficacy of biogas to check infestation of *Callosobruchus maculatus* fab. infesting stored green gram, *Vigna radiata* Linn. *Journal of Research* **43**: 59-62.

Singh G, Thapar VK and Sethi PS 1994. Use of biogas for control of stored grain insect pests. *J of Insect Sci* 7: 40-42.

TEAP 2000. Report of the Technology and Economic Assessment Panel. In: Kuijpers L (Ed), April 2000. UNEP, Nairobi.

Tiwari BK, Brennan CS, Curran T, Gallagher E, Cullen PJ and Donnell CP 2010. Application of ozone in grain processing. *J Cereal Sci* **51**: 248-255.

Tunc I, Berger BM, Erler F and Dagli F 2000. Ovicidal activity of essential oils from five plants against two stored-product insects. *J Stored Prod Res* **36**: 161-168.

Weast RC, Astle MJ and Beyer WH 1986. CRC Handbook of Chemistry and Physics,67th edition, CRC Press, Inc. Boca Raton, Florida.

Weaver DK and Subramanyam B 2000. Botanicals. In: Subramanyam B, Hagstrum D W (Eds), *Alternatives to Pesticides in Stored-Product IPM*. Pp 303-320. Kluwer Academic Publishers, Massachusetts.

White NG and Leesch JG 1996. Chemical control in integrated management of insects in stored-products. In:Subramanyam B and Hagstrum D W (Eds), *Integrated Management of Insects in Stored-Products*. pp. 41–70. Marceln Dekker, Inc., New York, USA,

Wright EJ 2000. Carbonyl sulfide: progress in research and commercialization of a new commodity fumigant *Proc Ann Int Res Conf on Methyl Bromide Alternative and Emissions Reductions*. pp 86-93. Florida, USA.

Wright EJ 2003. Carbonyl sulfide (COS) as a fumigant for stored products: progress in research and commercialisation. In: Stored Grain in Australia 2003: *proc of the Australian Postharvest Tech Conf.* pp. 224–229 Australia.

White NDG and Leesch JG 1996. Chemical control. In: *Integrated management of insects in stored products* (Subramanyam B and Hagstrum DW). pp. 287-330. New York: Marcel Dekker.

Zettler JL and Arthur FH 2000. Chemical control of stored product insects with fumigants and residual treatments. *Crop Prot* **19**: 577–582.

Zettler JL Leesch JG, Gill RF and Tebbets JC 1999. Chemical alternatives for methyl bromide and phosphine treatments for dried fruits and nuts. *Proc of the 7th Int Working Conf on Stored Prod Prot.* Pp 554-561.China.

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Fertigation technology for enhancing nutrient use and crop productivity: An overview

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Abstract

Fertigation - a technique of application of fertilizers along with irrigation water, provides an excellent opportunity to maximize yield and minimize environmental pollution. Fertigation ensures availability of fertilizer nutrients in the root zone in readily available form and therefore, minimize fertilizer application rate and increases fertilizer use efficiency. The associated increase in yield with minimum fertilizer application rate, increases return on the fertilizer invested. Based on experimentation, it has been observed that fertigation leads to saving of fertilizer by 25-40%, increased returns and reduced leaching of the nutrients. The present paper is an attempt to review the work done on various aspects of fertigation technology.

Key words: Fertigation, NPK behaviour, Recommended doses of fertilizers, fertilizer saving

Sustained higher yield with high yielding varieties depends entirely on the sustainable use of the limited water and energy resources, specifically in developing countries with arid and semi-arid regions. Moreover, intensification of agricultural production to meet growing market demand requires the simultaneous application of irrigation water and fertilizers. Fertigation - a modern agro-technique provides an excellent opportunity to maximize yield and minimize environmental pollution (Hagin *et al*. 2002) by increasing fertilizer use efficiency, minimizing fertilizer application and increasing return on the fertilizer invested.

What is fertigation?

The practice of supplying crops in the field with fertilizers *via* the irrigation water is called fertigation. In fertigation, timing, amounts and concentration of fertilizers applied are easily controlled. Fertigation allows the landscape to absorb up to 90% of the applied nutrients, while granular or dry fertilizer application typically result in absorption rates of 10 to 40% (Table 1). Fertigation ensures saving in fertilizer (40-60%), due to "better fertilizer use efficiency" and "reduction in leaching" (Kumar and Singh 2002).

Drip irrigation is often preferred over other irrigation methods because of the high water-application efficiency on account of reduced losses, surface evaporation and deep percolation. Because of high frequency water application, concentrations of salts remain manageable in the rooting zone. The regulated supplies of water through drippers not only affect the plant root and shoot growth but also the fertilizer use efficiency. Fertigation through drip irrigation reduces the wastage of water and chemical fertilizers, optimizes the nutrient use by applying them at critical stages and at proper place and time, which finally increase water and nutrient use efficiency. Moreover, it is well recognized as the most effective and convenient means of maintaining optimal nutrient level and water supply according to crop development stage, specific needs of each crop and type of soil.

Table 1. Fertiliser use efficiency (%) in fertigation

Nutrient	Soil application	Drip + soil application	Drip + fertigation
N	30-50	65	95
P_2O_5	20	30	45
K_2O	60	60	80

Fertiliser Marketing News, 2010

Significance of fertigation

Deficiency of N, P and K is a major production constraint in sandy soils, which have inherent constraints like P fixation, rapid hydraulic conductivity, faster infiltration rate, leaching of basic cations and low CEC. Hence, the cultivated crop in this soil requires large quantity of nutrients to support its growth and yield. Considering the soil and crop constraints, fertilizers should be applied in synchrony with crop demand in smaller quantities during the growing season. The right combination of water and nutrients is a prerequisite for higher yields and good quality production. The method of fertilizer application is also important in improving the use efficiency of nutrients. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand. Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses (Mmolawa and Or 2000).

Similar to frequent application of water, optimum split applications of fertilizer improves quality and quantity of crop yield than the conventional practice. Yield responses to the time of N and K application, either pre plant only or pre plant with fertigation, were dependent upon soil type. Less yield response resulted with fertigated N on heavier soils, compared to the lighter fine sands. Similar experiments on fine sands also indicated late season extra large and large fruit yields with 60% drip applied N and K compared to yield response with all pre-plant applied N and K. Researchers noted that drip-applied nutrients extended the season of large fruit harvest by maintaining plant nutrient concentrations late in the season. However, proper fertigation management also requires the knowledge of soil fertility status and nutrient uptake by the crop.

Monitoring soil and plant nutrient status is an essential safeguard to ensure maximum crop productivity. Soil properties, crop characteristics and growing conditions affect the nutrient uptake (Mmolawa and Or 2000). Fertigation enables the application of soluble fertilizers and other chemicals along with irrigation water, uniform and more efficient. Nevertheless, the increasing uses of nitrogenous fertilizers have caused environmental problems, generally manifest in groundwater contamination. There is a direct relation between large NO_3-N losses and inefficient fertigation and irrigation management. Therefore, water and N fertilizer inputs should be carefully managed in order to avoid losses.

Improved water use efficiency under drip irrigation, by reducing percolation and evaporation losses, provides for environmentally safer fertilizer application through the irrigation water (Mmolawa and Or 2000). The overall problem is to identify economically viable practices that offer a significant reduction of NO_3-N losses, which also fit in the farming systems practised under a particular soil type and set of climate conditions. NO_3-N is very mobile and if there is sufficient water in the soil, it can move quickly through the soil profile. Careful application of nitrogen and water should be able to minimize the amount of nitrogen moving below the root zone.

The method of fertilizer application is very important in obtaining optimal use of fertilizer. It is recommended that fertilizer should be applied regularly and timely in small amounts. This will increase the amount of fertilizer used by the plant and reduce the amount lost by leaching (Shock *et al*. 2003).

Hypotheses for fertigation techniques

1. Fertigation enhances fertilizer use efficiency by 40-60%, hence recommended doses of fertilizers may be reduced proportionally
2. Drip irrigation promotes root growth in surface layer (about 70-80%), hence the nutrients from sub-surface layers may not be extracted
3. Drip irrigation leads to moisture content around/above

field capacity hence may promote leaching of nutrients

4. Use of water soluble fertilizers (WSF) may lead to leaching losses beyond surface layer, hence frequent split application of WSF is desirable
5. The frequency of fertigation may increase with fertilizers doses in order to avoid leaching losses or toxicity if any

Fertigation scheduling

Factors that affect fertigation module are soil type, available NPK status, organic carbon, soil pH, soil moisture at field capacity, available water capacity range, aggregate size distribution, crop type and its physiological growth stages, discharge variation and uniformity coefficient of installed drip irrigation system.

The efficient fertigation schedule needs following considerations *viz*.

1. crop and site specific nutrient management,
2. timing nutrient delivery to meet crop needs and
3. controlling irrigation to minimize leaching of soluble nutrient below the effective root zone.

In many situations, a small percentage of N and K (20 -30%) and most or all P is applied in a pre-plant broadcast or banded application especially in the areas where either initial soil levels are low or early season irrigation is not required. Pre plant application of P is common since soluble P sources (Phosphoric acid) are costlier than granular forms, to avoid the chemical precipitation in drip line and the movement of drip applied P away from the injection point is goverened by soil texture and soil pH. Movement of P is particularly restricted in fine textured and alkaline soil. When making a pre-plant application of any nutrient, it is important that the fertilizer be placed within the wet zone of the drip system.

A crop specific fertigation schedule can be developed using growing degree days implementation. A soil with high N supply capacity may require substantially low N fertilizers. Application of N and K in excess of crop requirement can have adhesive effect such as ground water contamination with nitrate N, appearance of blossom end rot in tomato or pepper with heavy ammonical N application, reduction in specific gravity of potato and size of straw berry fruit with excessive K fertilization.

Nutrient can be injected daily or bimonthly depending upon system design, soil type and farmer's preference. Frequent injection may be needed for sandy soil with poor water and nutrient capacity and grower who want to reduce injection pump size and cost. Since leaching is possible with drip irrigation, nutrient applied in any irrigation must not be subjected to excessive irrigation during that application or in subsequent irrigations. It is possible to irrigate nutrient in non continuous (bulk) or continuous (concentration) fashion. Fertilizer should be injected in a period such that enough time remains to permit complete flushing of the system without over irrigation. Water that moves below the active crop root zone carry nitrate N or K in substantial quantities. One cm of leachate at 100 mg nitrate N/litre would contain 10 kg N/ha.

Drip irrigation introduces possibilities for precise application of fertilizer and other chemicals. The restricted root growth necessitates the type of fertilizer application "fertigation", which prevents nutrient deficiencies. The high efficiency of water application reached in drip irrigation systems is ideal for the high efficiency of applied nutrients in fertigation. But, some of these potential benefits can reverse into disadvantages when the irrigation system design or management is not correct (non uniform nutrient distribution, over-fertigation, excessive leaching, clogging).

Behaviour of Plant Nutrients during fertigation

Nitrogen

In fertigation, applied urea travels with the water in the soil. Its distribution in the soil wet zone depends on the timing of its incorporation with the irrigation water. When added during the third quarter of the irrigation cycle, followed by the flushing of the remaining irrigation cycle, the fertigated urea on reaching the boundaries of the wet zone becomes susceptible to volatilization. Evaporation from the soil surface results in increased urea concentration near the soil surface. This residual urea at the soil surface is also certain to be lost to the atmosphere as ammonia. Ammonium (NH_4^+) carries a positive electric charge (cation) and is adsorbed to the negatively charged sites on clay and can also replace other adsorbed cations on the clay surfaces. These are mainly Ca and Mg that constitute the major sorbed cations in the soil. As a result of these interactions, ammonium is concentrated near the dripper and the displaced Ca and to a lesser extent Mg, travels with the advancing water. Within a few days, the soil ammonium is usually oxidized by soil bacteria to the nitrate form that is dispersed in the soil with further irrigation cycles. When either ammonium or urea is used as nitrogen source in fertigation, significant gaseous losses as nitrous and nitric oxide has also been recorded (Hoffman and Van Cleemput 2004).

Nitrate (NO_3^-) carries a negative electric charge (anion). It cannot, therefore, bind to the clay particles of basic and neutral soils which carry negative charges. However, nitrate binds to positively charged iron and aluminum oxides present in acid soils. As in the case of urea, nitrate travels with the water and its distribution in the soil depends on the timing of its injection to the irrigation line.

Phosphorous

Phosphorus (P) in solution is subject to interactions with inorganic and organic constituents in the soil. The $H_2PO_4^-$ ion remains stable in the solution inside the irrigation line as long as the pH is kept low. Once it is released to the soil it reacts very quickly with clay minerals like, montmorillonite and illite in basic soils and with kaolinite clay, iron and aluminum compounds in acid soils. P reacts mainly with lime ($CaCO_3$) in basic soil conditions. The range of relatively insoluble chemical products of P with soil constituents is so large that it is generally called "fixed P."

The rapid reactions of phosphate with Ca (lime rich soils) in basic soils and with Fe and Al in acid soils restrict the distance of movement of applied P in the soil. The higher the clay content or $CaCO_3$ fraction of the soil, the shorter is the distance of movement of P from the dripper. Even in sandy soils (Ben Gal and Dudley 2003), the distance travelled by P is quite limited as compared with the water. When the P is complexed by organic compounds like in manures, it does not react with soil constituents and therefore, can travel to considerable distances from its point of application in the soil. The leaching of P through the soil profile is commonly thought to occur only in coarsely structured soils due to the rapid infiltration of water and in sandy soils due to the absence of active sites for P sorption.

Potassium

Drip irrigated crops under strict water control usually develop restricted root volume. The amounts of K present as exchangeable cation on clay surfaces or as K within the crystal lattice of illite clay particles in the soil might not be sufficient to completely meet plant needs for K. Since high K contents are present in harvested fresh vegetables, fruits, fresh leaves, tubers and root crops, large amounts of K are exported from the field. A continuous supply of K during fertigation is, therefore, required to ensure plant growth, quality and yield. In practice, the exact distribution of K in the soil from the drip point is of less importance since the roots can grow and find the K in the wet root zone. The efficiency of the plant roots to take up K is so high that whenever the root meets a K source it is easily taken up. In sand dunes with low soil K content, fertigation with daily supply of K and N is needed to ensure their supply to plants, particularly if there is restricted root volume. When the soil does not adsorb K due to low level of clay content, K distribution is typically larger than that of P distribution, but less than that of N. This was demonstrated in a fertigated field grown tomato on soil containing 95% calcium carbonate with low CEC (Kafkafi and Bar Yosef 1980).

Crop response to fertigation

All crops respond to fertigation. However, much work has been concentrated on high value crops (Solaimalai *et al.* 2005) such as potato (Badr *et al*. 2011), capsicum (Brahma *et al*. 2010; Gupta *et al.* 2009; Srinivas and Prabhakar 1982), onion (Ewais *et al*. 2010), medicinal coleus (Kennam 2008), cucumber (Moujabber *et al*. 2002), Broccoli (Sanchita *et al*. 2010), tomato (Shedeed *et al*. 2009), pointed gourd (Singandhupe *et al*. 2007), turmeric (Syed Sadarunnisa *et al*. 2010), tomato (Tan *et al*. 2009; Tanaskovik *et al*. 2011) and some leafy vegetables (Ueta *et al*. 2009). Fertigation gave 40% saving of fertilizer nutrients without affecting the yield of crops compared to the conventional method of nutrient application (Sathya *et al*. 2008). Keng *et al*. (1979) showed that the yields from broadcast fertilizer treatments were 15.8% lower than that from fertigation and 12.3% lower than that from banded fertilizer application.

Sweet pepper: Kaushal *et al*. (2012) reported that the drip irrigation adoption increased water use efficiency (60-200%), saved water (20-60%), reduced fertilization requirement (20-33%) through fertigation, produced better quality crop and increased yield (7-25%) as compared with conventional irrigation.

Lady's finger: Rekha and Mahavishnan (2008) reported the water and fertilizer saving by 40-70 and 30-50%, respectively through drip fertigation in lady's finger.

Celery: Kaniszewski *et al*. (1999) reported that fertigated celeriac plants had greater leaf area, dry matter production, and nitrate-N and total N contents than those given through broadcast N with or without drip irrigation.

Cauliflower: Kapoor *et al.* (2014) showed that increase in NPK fertigation level from 33.3 to 100% RDF significantly increased number of leaves, relative leaf water content, marketable yield of cauliflower and benefit cost ratio but decrease in fertilizer expense efficiency. Drip based irrigation along with fertigation in general had higher fruit yield but lower benefit cost ratio in comparison to flood and conventional fertilizer application. At Palampur fertigation using water soluble fertilizers increased marketable yield in cauliflower by 21.3% as compared to conventional application of fertilizers (Table 2).

Broccoli: At Palampur fertigation using water soluble fertilizers increased marketable yield in broccoli by 21.4% as compared to conventional application of fertilizers (Table 2). However, when 25% nutrients were applied as basal through conventional fertilizer and 75% nutrient through fertigation using water soluble fertilizers increase in marketable yield in broccoli was 12.3% as compared to conventional application of fertilizer (Table 3).

Brinjal: At Palampur, when 25% nutrients were applied as basal through conventional fertilizer and 75% nutrient through fertigation using water soluble fertilizers increase in marketable yield in brinjal was 15.4% as compared to conventional application of fertilizer (Table 3).

Chilli: Veeranna *et al*. (2001) reported that 80% water soluble fertilizer (WSF) was effective in producing about 31 and 24.7% higher chilli fruit yield over soil application of normal fertilizers at 100% recommended level in furrow and drip irrigation methods, respectively, with 20% of saving in fertilizers. Roy *et al*. (2011) showed in capsicum that the length and width of fruit and number of fruits per plant increased significantly with increasing nitrogen doses up to 100 kg N/ha. However, average weight of fruit increased significantly with increasing levels of P up to 150 kg N/ha. Average weight of fruit and yield increased significantly with increasing levels of P up to the treatment 30 kg P/ha, whereas length of fruit and number of fruits per plant was increased significantly up to the 60 kg P/ha. Considering the combined effect of nitrogen and phosphorus, the maximum yield was recorded in the treatment combination of 150 kg N and 30 kg P /ha. At Palampur fertigation using water soluble fertilizers increased marketable yield in capsicum by 15.1 as compared to conventional application of fertilizers (Table 2). The fertigation schedule was developed for protected conditions and 4.6 B.C ratio was obtained with capsicum (Table 4).

Tomato: Hebbar *et al*. (2004) showed that fertigation with 100% water soluble fertilizers (WSF) increased the tomato fruit yield significantly over furrow-irrigated control and drip irrigation. The fertigation schedule was developed for protected conditions in tomato and a B.C ratio of 5.4 was obtained (Table 4).

Cucumber: Ibrikci and Buyuk (2002) obtained higher yield and leaf N, P and K content in drip fertigated cucumber than furrow irrigated plants. Beyaert *et al*. (2007) showed that drip irrigation coupled with fertigation showed significant advantages in terms of yield and economic returns of cucumber compared with overhead irrigation and conventional fertilization practices. The fertigation schedule was developed for protected conditions and 3.3 B.C ratio was obtained with cucumber (Table 4).

Table 2. Fertilizer schedule without basal doses & 100% RDF through fertigation

Crop	Growing season	Fertigation dose per spilt (g/m^2)*			No of splits	Fertigation frequency (days)	Increase in yield compared to conventional fertilizer	B.C ratio
		19:19:19	0:0:50	Urea				
Cauliflower	Oct- Feb	2.9	0.3	1.5	10	8-10	21.3 %	2.1
Broccoli	Oct-Feb	4.0	-	1.6	10	8-10	21.4 %	3.7
Capsicum	Apr- July	3.0	-	1.5	10	8-10	15.1%	3.9

*No basal dose is applied and fertigation is initiated from 15 days after transplanting and fertigation doses are completed before flowering / fruit setting

Table 3. Fertilizer schedule with 25% of RDF through basal and 75% of RDF through fertigation

Crop	Basal doses			Fertigation dose per spilt (g/m^2)*			No of splits	Fertigation frequency (days)	Increase in yield compared to conventional fertilizer	B . C ratio
	Urea	SSP	MOP	19:19:19	12:61:0	Urea				
Broccoli	8.2	15.7	2.3	2.0	0.8	3.1	7	8-10	15.4 %	3.1
Brinjal	5.4	9.4	2.1	2.7	0.2	8.6	7	8.10	12.3 %	2.6

*25% of RDF applied as basal doses and fertigation is initiated from 30 days after transplanting and fertigation doses are completed before flowering / fruit setting

Table 4 . Drip fertigation schedule under protected cultivation

Crop	Basal dose (g/m^2)			Fertigation dose/spilt (g/m^2)				Fertigation interval (days)	B.C ratio
	Urea	SSP	MOP	19:19:19	12:61:0	Urea	No of splits		
Tomato	14*	34	4	1.2	0.4	0.7	28	5 -7	5.4
Capsicum	10	22	4	1.2	0.1	0.3	28	5 -7	4.6
Cucumber	12	18	6	3.0	2.3	1.2	10	5 -7	3.3

Onion: Chopade *et al*. (1998) found that drip irrigation with the recommended rate of solid fertilizer in two applications gave the highest onion bulb yield while drip fertigation at 50% of the recommended rate gave the highest bulb quality. Rumpel *et al*. (2004) obtained higher marketable onion yields when the 50 kg/ha N rate was applied through drip fertigation (41% increase) and highest after applying 150 kg ha^{-1} N through fertigation (79% increase) as compared to the control (without fertigation and irrigation). Dingre *et al*. (2012) showed that drip fertigation resulted into 12 to 74% increase in the productivity of onion seed as compared to conventional method. The total irrigation water applied through surface and drip system was 840 mm and 520.45 mm indicating 39% water saving whereas, field water use efficiency of drip fertigation was more by 2.5 times as that of control. Rajput and Patel (2006) recorded the highest onion yield in daily fertigation followed by alternate day fertigation. Lowest yield was recorded in monthly fertigation frequency. Bhakare and Fatkal (2008) showed that the onion seed yield increased and yield contributing characters improved with fertigation levels with maximum in 125% recommended dose of fertilizer (RDF) fertigation treatment which was at par with 100% RDF fertigation treatment. The treatment 75% RDF through fertigation was significantly superior to application of 100% RDF through conventional fertilizer and as such, there could be a saving of 25% of the added fertilizer..

Pea: Singh *et al.* (2006) showed that the increase in N through fertigation caused increased in green pea yield at all the levels of drip irrigation (0.5 Epan, 0.75 Epan and 1.0 Epan), but the magnitude of increase was highest at lowest level of water supply.

References

Badr MA, Taalab AS and Tohamy El WA. 2011. Nitrogen application rate and fertigation frequency for drip irrigated potato. *Australian J Basic and Applied Sci* **5**: 817-825

Ben Gal A and Dudley LM. 2003. Phosphorus availability under continuous point source irrigation. *Soil Sci. Soc. Am. J.* **67**:1449-1456.

Beyaert RP, Roy RC and Coelho BBR. 2007. Irrigation and fertilizer management effects on processing cucumber productivity and water use efficiency. *Canadian J Plant Sci* **87**: 355–363

Bhakare BD and Fatkal YD. 2008. Influence of micro irrigation and fertilizer levels on growth, yield and quality of onion seed. *J Water Mangnt* **16**: 35-39

Brahma S, Saikia L, Barua P, Hazarika T and Sharma B 2010. Studies on effect of fertigation with different levels of N and K fertilizers on growth, yield, quality and economics of early season capsicum (*Capsicum annum* L. *var. grossum*) under cover. *Veg Sci* ***37*** :160-163.

Chopade SO, Bansode PN, Hiwase SS and Bhuyar RC 1998. Effect of drip fertigation on physiological growth of onion. *Annals Plant Physio* **11**: 45-48

Dingre SK, Pawar DD and Kadam KG 2012. Productivity, water use and quality of onion (*Allium cepa*) seed production under different irrigation scheduling through drip. *Indian J Agron* **57**:186-190

Ewais MA, Mahmoud AA and Khalil AA. 2010. Effect of nitrogen fertigation in comparison with soil application on onion production in sandy soils. *Alexandria Jf Agri Res* **55**: 75-83

Gupta AJ, Chattoo MA and Bhat FN 2009. Techno-economic evaluation of drip irrigation and fertigation practices in capsicum under Kashmir conditions. *Veg*

Sci ***36*** :309-314.

Hagin J, Sneh M and Lowengart-Aycicegi A 2002. Fertigation – Fertilization through irrigation. IPI Research Topics No. 23. Ed. by A.E. Johnston. International Potash Institute, Basel, Switzerland.

Hebbar SS, Ramachandrappa BK, Nanjappa HV and Prabhakar M. 2004. Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *European J Agron* **21**: 117-127

Hofman GJ and Van Cleemput O. 2004. Soil and plant nitrogen. International Fertilizer Industry Association (IFA), Paris, France.

Ibrikci GS and Buyuk H. 2002. Yield and elemental composition of cucumber as affected by drip and furrow irrigation. *Acta Hort* **571**: 51-57.

Kafkafi U and Bar-Yosef B. 1980. Trickle irrigation and fertilization of tomatoes in high calcareous soils. *Agron. J.* 72:893-897.

Kaniszewski S, Rumpel J and Dysko J. 1999. Effect of drip irrigation and fertigation on growth and yield of celeriac (*Apium graveolens* L. var. *rapaceum* (Mill.) *Gaud*). *Veg Crops Res Bulletin* **50**: 31-39

Kannan K. 2008. Effect of irrigation method, drip irrigation regimes and fertigation schedules on growth and yield of medicinal coleus (*Coleus forskohlii*). *Indian J Agri Sci* **78** : 614-617

Kapoor R, Sandal SK, Sharma Sanjay K, Kumar A and Saroch K. 2013. Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics, productivity and water use efficiency of cauliflower (*Brassica oleracea* var. *Botrytis)* in wet temperate zone of Himachal Pradesh. *Indian J Soil Cons* **42**: 249 -254

Kaushal A, Lodhi AS and Singh KG. 2011. Economics of growing sweet pepper under low tunnels, *Prog Agri* :67-72.

Keng JCW, Scott TW and Lugo LMA 1979. Fertilizer management with drip irrigation in an Oxisol. *Agron J* **71** : 971-980.

Kumar A and Singh AK 2002. Improving nutrient and water use efficiency through fertigation. *J Water Mangnt* **10**: 42-48.

Mmolawa K and Or D 2000. Root zone solute dynamics under drip irrigation: A review. Plant and Soil 222:163-190. Netherlands, 27 pp.

Moujabber EI, Atallah M and Darwish T. 2002. Crop modeling and water use efficiency of protected cucumber. *Int Atomic Energy Agency Tech Documents* **1266**: 61-67

Rajput TBS and Patel N. 2006. Water and nitrate movement in drip-irrigated onion under fertigation and irrigation treatments. *Agric Water Mangnt* **79**: 293-311

Rekha BK and Mahavishnan K. 2008. Drip fertigation in vegetable crops with emphasis on lady's finger (*Abelmoschus esculentus* (L.) *Moench*) – A Review. *Agri Rev* **29** : 298 – 305.

Roy SS, Khan MSI and KK Pall 2011. Nitrogen and phosphorus efficiency on the fruit size and yield of capsicum. *J Expt Sci* **2**: 32-37.

Rumpel J, Kaniszewski S and Dysko J. 2004. Effect of drip irrigation and fertilization timing and rate on yield of onion. *J Veg Crop Production* **9**: 65-73

Sanchita B, Phooken DB, Kachari M, Hazarika TK and Das K. 2010. Growth, yield and economics of broccoli under different levels of nitrogen fertigation. *Indian J Hort* **67**: 279-282

Sathya S, Pitchai JG, Indirani R and Kannathasan M. 2008. Effect of fertigation on availability of nutrients (N, P & K) in soil – A Review. *Agri Rev* **29**: 214-219

Shedeed SI, Zaghloul SM and Yassen AA. 2009. Effect of method and rate of fertilizer application under drip irrigation on yield and nutrient uptake by tomato. *Ozean J Applied Sci* **2**: 139-147

Shock CC, Feibert EB, Saunders LD and James SR. 2003. Umatilla Russet' and `Russet Legend' Potato Yield and Quality Response to Irrigation. *Hort Sci* 38: 1117 -1121.

Singandhupe RB, James BK, Edna A and Nanda P. 2007. Response of drip irrigation and mulching on growth and fruit yield of pointed gourd (*Trichosanthes dioica*). *Indian J Agri Sci* **77**: 8-13

Singh KG, Siag M and Mahajan G. 2006. Water and nutrient requirement of drip irrigated green pea. *Haryana J Hort Sci* **35**: 320-322

Solaimalai A Baskar, Sadasakthi M A and Subburamu K 2005. Fertigation in high value crops, *Agriculture Review* ***26*** :1-13.

Srinivas K and Prabhakar BS. 1982. Response of capsicum to nitrogen fertilization. *Veg Sci* **9**: 71-74.

Syed Sadarunnisa, Madhumathi C, Rao GS and Sreenivasulu B 2010. Effect of fertigation on growth and yield of turmeric cv. Mydukur. *J Hort Sci* **5** : 78-80.

Tan CS, Zhang TQ, Reynolds WD, Warner J and Drury CF. 2009. Farm-scale processing tomato production using surface and subsurface drip irrigation and fertigation. *Acta Hort* **823** : 77-81.

Tanaskovik V, Cukaliev O, Romic D and Ondrasek G. 2011 The influence of drip fertigation on water use efficiency in tomato crop production. *Agriculturae Conspectus Scientificus* **76**: 57-63.

Ueta T, Ikeba T, Ahn-DongHyuk, Kato K, Kawano T and Matsumoto E. 2009. Effects of drip fertigation on yield and quality of leaf vegetables and on efficiency of nitrogen fertilization in outdoor plant. *Japanese J Soil Sci and Plant Nutrition culture.* **80**: 477-486.

Veeranna HK, Kgalak abdul, AA, Sujith GM. 2001. Effect offertigation with normal and water soluble fertilizers compared to drip andfurrow methods on yield, fertilizer and irrigation water use efficiency in chilli.*Micro Irrigation* pp. 461-466.

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Intensification of cropping through introduction of second crop after peas in Lahaul valley of Himachal Pradesh

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Abstract

A field experiment consisted of seven pea based cropping sequences *viz*. Pea-mustard 'NDRE 4', Pea-mustard 'JD 6', Pea-toria 'Bhawani', Pea-local sarson 'Yungar', Pea-French bean 'Contender', Pea-buckwheat 'Local' and Pea-buckwheat 'USDA' was conducted at Kukumseri (Lahaul and Spiti) during 2010 and 2011 to find out the most remunerative second crop after main pea crop for dry temperate conditions of western Himalayas. The local sarson 'Yunger' took the least days (58 days) for maturity closely followed by French bean. Buckwheat USDA took highest number of days (92) to mature. Among new introduced mustard varieties 'NDRE 4' took 81 days. The highest pea equivalent yield (6377 kg/ha) with net return of INR 86714/ha and B: C ratio of 1.82 was obtained from pea-Frenchbean 'Contender' sequence followed by pea-mustard 'NDRE 4' (5561 kg/ha) with net return of INR 81478/ha and B: C ratio of 1.86. The increase in yield and net return with the best sequence (pea – Frenchbean 'Contender) over the most prevalent pea- local sarson 'Yunger' sequence was 24.9 and 23.8%, respectively.

Key words: Pea, cropping sequence, economics

Several studies were undertaken on crop diversification and intensification in low and mid hills of Himachal Pradesh (Sharma *et al*. 2007, 2008, 2009; Rana *et al.* 2010, 2011). However, in the high hills zone of Himachal Pradesh where cropping season is limited, studies on intensification of cropping are scanty (Rana *et al.* 2003; 2005; 2006; Sharma *et al.* 2015). The cropping season in this dry temperate area is very short starting from Mid March or First week of April till October at the most. Lahaul & Spiti district of Himachal Pradesh falls under high hill dry temperate zone in north western Himalayas. In most part of Lahaul valley only one crop mainly pea is taken. But with increase in temperature in last few years in later part of year *i.e.* August to October, a short duration second crop was also cultivated by the farmers. The pea crop vacate the field in early to mid July and the time left for the second crop before onset of winter is 80-90 days. The second crop of buckwheat or local sarson 'Yunger' cultivated after pea are low yielders. Thus, there is scope for introduction of remunerative crops with maturity duration of 80-90 days. Keeping these facts in view, introduction of new genotypes of rapeseed – mustard and other crops which can best fit in the short cropping duration of this valley and help in increasing the productivity and profitability per unit area and time was required to be undertaken.

Materials and methods

The experiment was conducted at Kukumseri (32°46'15" N latitude; 76°41'23" E longitude and 2734 m altitude) during 2010 and 2011. The climate of the site was extremely cold and heavy snowfall occurs during winter. The temperature remains several degrees below zero. Single cropping season was prevailing in the region which starts from April to September or early October when the mean minimum and maximum temperature ranges between 12°C to 24°C.

There was negligible rainfall followed by high light intensity and low humidity. Average annual rainfall of the region was 250 mm. The soil of the site was sandy loam with organic carbon of 0.3% and pH 6.9. Soils were shallow in depth and loose in texture resulting in poor water holding capacity. The available nitrogen, phosphorus and potassium were medium, high and low, respectively. The experiment consisted of seven cropping sequences *viz*., pea -mustard 'NDRE 4', pea-mustard 'JD 6', pea-toria 'Bhawani', pea-local brown sarson 'Yunger', pea-French bean 'Contender', pea- buckwheat 'local' and pea- buckwheat 'USDA' was laid out in randomized block design with three replications. The pea crop was planted on 28 March and 24 March during first and second year, respectively. The pea crop was harvested on 14th and 11th July in respective years. The second crop in a sequence was sown immediately after the harvest within two days. All the crops were sown with recommended package of practices under irrigated condition. Snow-melt water, the only source of irrigation was used to irrigate crops through sprinklers, rain gun or *Kuhl*. The rest of the management practices were in accordance with the recommended package of practices for the individual crops. The crops were harvested from net plot. For comparison between crop sequences, the economic yields of crops were converted into pea equivalent on price basis. Land utilization efficiency was worked out by summation of duration of each crop under individual crop sequence divided by 365. Production efficiency (kg/ha/day) was obtained by dividing total production in terms of pea equivalent in a sequence by the total duration of year (365), while profitability (INR/ha/day) was obtained by dividing net monetary return by 365. Economics of cropping sequences was computed based on prevalent market prices.

Results and Discussion

Crop phenology and yield

The local sarson 'Yangur' was the earliest to mature in 58 days followed by French bean and local variety of buckwheat, each in 66 days (Table 1). Among the improved varieties of rapeseed mustard, toria 'Bhawani' matured in 67 days followed by mustard variety 'NDRE 4' in 81 days. The only second crop to mature after 90 days was buckwheat variety 'USDA'. The mustard cultivar 'JD 6' was also late maturing (86 days). Cultivated land utilization index owing to double cropping increased from 29.7% under the single cropping of peas to 45.6-54.9%. This is clearly indicated that even after the best utilization of the land under cropping, the cropping season can hardly be extended beyond 55% time of the year. For the next five to six winter season months when the area faces extreme cold with occasional snowfall, some suitable strategy needs to be worked out for the region. In these areas the cultivated duration can best be extended by promoting greenhouse/polyhouse technology. For this policy and research interventions must need due attention. Similar efforts as in the present study, few efforts were also made by earlier workers to extend the cropping season in these areas (Rana *et al.* 2003; 2005; 2006; Sharma *et al.* 2015).

The data on yield of different crops are summarized in Table 2. The highest pea equivalent yield (6377 kg/ha) was obtained from Pea-French bean 'Contender' sequence followed by Pea-mustard 'NDRE 4' (5561 kg/ha) and Pea-toria 'Bhawani' (5239 kg/ha). The increase in pea equivalent yield over the most prevalent pea – local sarson 'Yunger' sequence with these three better sequences was 24.9, 8.9 and 2.6%, respectively. The pea-buckwheat sequences were the lower yielders. The matter of caution here is that while sowing second crop in sequence, it must gets at least 80 days maturity duration before temperature will go drastically down by mid October. Although pea-French bean sequence is the highest yielder but its bulk transfer in case of early snowfall will be a concern and at same time it will compete with the produce from the lower belt. Hence, the second best option after peas could be toria variety 'Bhawani' or mustard variety 'NDRE 4' for the marginal farmers of valley. Owing to higher pea equivalent yield, productivity efficiency was highest under pea – French bean 'Contender' (17.5 kg/ha/day) followed by pea – mustard 'NDRE 4' (15.2 kg/ha/day) (Table 3).

Economics

The highest net returns were obtained from Pea-Frenchbean 'Contender' cropping system (INR 86,714) followed by pea-mustard 'NDRE 4' (INR 81,478) (Table 3). Similarly profitability was highest under pea – French bean 'Contender' cropping system (INR 238/ha/day) followed by pea-mustard 'NDRE 4'. However, the B:C ratio was highest from pea-mustard 'NDRE 4' (1.86). This was followed by pea – French bean 'Contender'. The net returns and the B:C ratio were lowest when buckwheat was taken as second crop.

Conclusively the traditional pea-local sarson 'Yunger' sequence can be replaced with most remunerative pea – French bean 'Contender' sequence. Alternatively, marginal farmers should adopt either pea - mustard 'NDRE 4' or Pea - toria 'Bhawani' if market is not available for French bean. These sequences can meet the oil requirement for the six months winter land locked valley.

Table 1. Days to maturity and cultivated land utilization index under different cropping sequences

Cropping sequence	Days to maturity						Land utilization index (%)		
	First crop			Second crop					
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Pea-mustard'NDRE 4'	108	109	108.5	80	82	81	51.5	52.3	51.9
Pea-mustard'JD 6'	108	109	108.5	89	83	86	54.0	52.6	53.3
Pea-toria'Bhawani'	108	109	108.5	69	65	67	48.5	47.7	48.1
Pea- local sarson 'Yungar'	108	109	108.5	59	57	58	45.8	45.5	45.6
Pea-Frenchbean 'Contender'	108	109	108.5	68	64	66	48.2	47.4	47.8
Pea-buckwheat'Local'	108	109	108.5	66	66	66	47.7	47.9	47.8
Pea-buckwheat'USDA'	108	109	108.5	94	90	92	55.3	54.5	54.9
LSD (P=0.05)	-	-	-	2.7	2.1	3.4			

Table 2. Production of pea based cropping sequences under dry temperate conditions in north western Himalayas

Cropping sequence	Green peas yield (kg/ha)			Second crop yield (kg/ha)			Pea equivalent yield (kg/ha)		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Pea-mustard'NDRE 4'	5560	4418	4989	520	614	567	6080	5042	5561
Pea-mustard'JD 6'	5390	4362	4876	430	549	490	5820	4891	5356
Pea-toria'Bhawani'	5420	4399	4910	309	355	332	5729	4748	5239
Pea- local sarson 'Yungar'	5380	4357	4869	240	243	242	5620	4594	5107
Pea-renchbean'Contender'	5490	4457	4974	1517	1570	1544	6754	6000	6377
Pea-buckwheat'Local'	5360	4383	4872	165	94	130	5470	4478	4974
Pea-buckwheat'USDA'	5410	4430	4920	22	56	39	5410	4507	4959
LSD (P=0.05)	NS	NS	NS	-	-	-	123.9	88.9	72

Table 3. Productivity and economics of pea based cropping sequences under dry temperate conditions in north western Himalayas

Cropping sequence	Productivity efficiency (kg/ha/day)	Net return (INR/ha)	Profitability (INR/ha/day)	B:C Ratio
Pea-mustard 'NDRE 4'	15.2	81,478	223	1.86
Pea-mustard 'JD 6'	14.7	76,913	211	1.76
Pea-toria 'Bhawani'	14.4	73,395	201	1.68
Pea- local sarson 'Yungar'	14.0	70,063	192	1.60
Pea-Frenchbean 'Contender'	17.5	86,714	238	1.82
Pea-buckwheat 'Local'	13.6	68,406	187	1.61
Pea-buckwheat 'USDA'	13.6	66,914	183	1.57
LSD (P=0.05)	-	-	-	-

References

Rana SS, Sood P, Mondal KK and Singh Y. 2003. Influence of varieties and fertility levels on pea and succeeding common buckwheat in pea- buckwheat cropping sequence. *Life Science Reporter* **5** (1&2): 16-19.

Rana SS, Rajinder Pal, Mondal KK and Sood P. 2005. Influence of seeding time of rajmash varieties intercropped with kalazira under dry temperate conditions. *Indian Journal of Pulses Research* **18** (2): 219-221.

Rana MC, Bindra AD and Rana SS. 2006. Identification of suitable varieties of pea and buckwheat for double cropping under dry temperate conditions of north-western Himalayas. Indian Journal of Agricultural Sciences **76** (4): 222-225.

Sharma SK, Rana SS, Sharma Sanjay K, Bhargava M, Sharma JJ and Sharma HL. 2007. Production potential and economic feasibility of irrigated rice based cropping sequences on cultivators' fields under sub-montane low hill conditions of Himachal Pradesh. *Himachal Journal of Agricultural Research* **33** (1): 110-112.

Sharma SK, Rana SS, Sharma Sanjay K, Subehia SK, Sharma JJ and Sharma HL. 2008. Production potential and economic feasibility of rice based cropping sequences on cultivators' fields under sub-montane low hills of Himachal Pradesh. Himachal Journal of Agricultural Research **34** (2): 5-9.

Sharma SK, Rana SS, Subehia SK, Sharma HL, Sharma JJ and Sharma Sanjay K. 2009. Evaluation of rice based cropping sequences on cultivators' fields in Una district of Himachal Pradesh. Himachal Journal of Agricultural Research **35** (2): 171-175.

Rana SS, Sharma JJ, Sharma HL, Sharma Sanjay K, Sharma SK, Saroch Kapil and Bhargava M. 2010. Production potential, sustainability and economic viability of rice based crop sequences under mid hills of Himachal Pradesh. Himachal Journal of Agricultural Research **36** (1): 7-12.

Rana SS, Sharma HL, Subehia SK, Negi SC and Sharma SK. 2011. Promising cropping systems for mid hill agro-climatic conditions of Himachal Pradesh. Himachal Journal of Agricultural Research **37** (2): 138-148.

Sharma Vishal, Kalia BD, Rana SS and Gupta Rahul. 2015. Effect of organic, biofertilizer and inorganic sources of nutrients on productivity and nutrient status of soil in garden pea based cropping sequence under Lahaul valley of Himachal Pradesh. Journal of Soil and Water Conservation **14** (2): 179-185.

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Effect of irrigation scheduling and NK fertigation on productivity of garden peas (*Pisum sativum* var. *hortense* L.)

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Abstract

A field experiment was conducted for three consecutive *rabi* seasons (2011-12 to 2013-14) to evaluate the effect of irrigation depth (0.4, 0.6, 0.8 and 1.0 CPE) and NK fertigation (50 and 100% of adjusted recommended dose) along with a control (basal application of soil test based adjusted recommended NPK fertilizer and surface irrigation of 5 cm) on the productivity of garden pea at Palampur. Result revealed that irrigation and fertigation with micro-sprinkler led to 60.9% less use of water and 10.0% higher green pod yield. Consequently, water use efficiency was increased by 3.12 times over the recommended practices. Every fifth day irrigation with 80% CPE (CPE 0.8) resulted in significantly higher green pod yield than every fifth day irrigation with either 60% CPE (13.74%) or 40% CPE (19.96%). Irrigation with minimum depth of water (0.4 CPE) resulted in maximum water use efficiency of 6.51 kg green pods m^{-3} of irrigation water used for crop production. Fertigation of sprinkler irrigated crop either with 50 or 100% of recommended soil-test based NK had no effect on green pod yield, gross return and water use efficiency.

Key words: Irrigation scheduling, fertigation, water use efficiency

India has made considerable progress in developing irrigation infrastructure which leads to substantial improvement in production of vegetables crops. Vegetable production increased from 12.06 lakh tonnes in 2009-10 to 12.69 lakh tonnes in 2010-11 with growth rate of 5.2% (Anonymous 2012). Despite this development the productivity of irrigated area has not reached the desired level. This is due to lower water use efficiency of traditional methods of surface irrigation, which is mainly due to higher water conveyance losses, excess or deficit application of irrigation water and deep losses. This necessitates adoption of such method of irrigation where losses are minimum. Pressurized micro sprinkler is one of such methods where controlled irrigation is possible with minimum losses of irrigation water. In India, due to special emphasis on micro-irrigation during 10th plan, the area under micro-irrigation increased up to 2352477 ha including 1270145 ha under micro sprinklers (Singh *et al*. 2012).

In Himachal Pradesh, area under micro-irrigation in poly-houses is 133.634 ha. Under open fields, it is 4461.519 ha with maximum area in Kangra district (842.56 ha) (Anonymous 2010). Micro-irrigation has an added advantage in undulating topography with poor soil water retention and transmission characteristics and small and scattered land holdings with small amount of water stored from rainfall at the farm. Among micro irrigation systems, sprinklers are favoured in comparison to drip as the time required in cleaning the blockages of emitters is eliminated considerably and water is delivered more uniformly to the crop. Micro and mini sprinklers are very reliable with a CV of <10%. They provide regular and targeted distribution of the irrigation water, valuable as a protection against damage from frost (Guidoboni 2006).

Application of water soluble fertilizer through venturi is an important feature of micro-irrigation systems. Fertigation increases the fertilizer use efficiency as the nutrients are supplied as per the demand of the crop. The availability of water and nutrient simultaneously improves the uptake.

Under such situation crop may need much less quantity of nutrient as it needs under conventional method of irrigation and fertilization. Sprinkler irrigation along with fertigation through water soluble fertilizers especially nitrogen and potash will optimize nutrient use and ultimately will increase water and nutrient use efficiency.

Pea (*Pisum sativum* var. *hortense* L.) is a cool-season, nutritious legume widely cultivated throughout the world. It is a rich source of protein (25%), amino acids, sugars (12%), carbohydrate, vitamins A and C, calcium and phosphorus, apart from having a small quantity of iron. Over years with steady increase in acreage and production, it has occupied the position of leading cash crop in Himachal Pradesh especially in the higher and mid hill zones of Himachal Pradesh. The area under pea crop in Himachal Pradesh is 22,800 ha with an annual production of 2,54,200 metric tonnes (Anonymous 2011). In low and mid – hill region of Himachal Pradesh, it is mostly grown as rainfed crop which is strongly influenced by low availability of soil moisture especially during initial growth and pod – formation/development stage as there is no rains from October-December and March-June. Inadequate soil moisture is usually a limiting factor in ensuring proper germination and early growth not only in rain-fed areas but also in *kuhl* (Snow fed gravity stream) irrigated areas where tail end farmers receive sub optimal irrigation water. In recent year's trend has been changed from more productivity per unit land to more productivity per unit water, as water is becoming increasingly scarce even in those areas where it was plentiful in recent past. It may be possible to maximize water productivity in pea by proper scheduling of irrigation. In the light of above a study was planned to study the effect of irrigation depth and NK fertigation through micro-sprinkler on crop productivity and water use efficiency.

Material and methods

A field experiment was conducted at Water Management Farm, CSK HPKV, Palampur during *rabi* 2011-12 to 2013-14 to optimize micro sprinkler irrigation and NK fertigation in garden pea. The area lies in Palam Valley (32^o06' 39.1" N latitude and 76^o32' 10.5" E longitude) perched in the lap of majestic snow clad Dhauladhar range of Himalayas at an elevation of 1290 m above mean sea level in Kangra district of Himachal Pradesh. The soil of the experimental field was silty clay loam in texture; acidic in reaction (pH 5.1); high in organic carbon (16.1 g/kg); medium in available nitrogen (246.5 kg/ha); high in available phosphorus (38.08 kg/ha) and low in available potassium (141.4 kg/ha). The experiment was laid out in

The experiment was laid out in factorial randomized block design with three replications. There were nine treatments, comprising of all the possible combinations of four irrigation depths (0.4, 0.6, 0.8 and 1.0 CPE) and two NK fertigation levels (50 and 100% of adjusted recommended dose) plus one control (basal application of soil test based adjusted recommended NPK fertilizer and surface irrigation of 5 cm).

The irrigation was applied through micro-sprinkler system at an interval of 4 days. The system consists of three micro-sprinklers per plot each having wetting diameter of 0.90 m. Mean evaporation rate of preceding 10 cropping seasons was calculated for estimation of irrigation water requirement. Irrigation requirement was calculated by taking into account the difference of average evaporation and rainfall (only positive values) and multiplying the cumulative average evaporation minus actual rainfall value with CPE ratio. In 'recommended practice', 5 cm deep flood irrigation was applied at 10 days interval. To ensure uniform crop stand, technique of water seeding of pea seeds in furrows was followed by application of water at 0.7 l m^{-1} furrow length before closing them.

The fertilizer dose was calculated by adjusting the recommended dose of NPK (50:60:60 kg/ha) based on soil test. Since, soil available P was in higher range, its dose was lowered by 25%. K was in lower range, so its dose was increased by 25%. The level of available N in soil was medium and therefore its dose was not altered. Thus, NPK dose used in present study was 50:45:75 kg/ha. In NK fertigation treatments, 1/3rd dose of NK was applied as basal. The remaining 2/3rd NK was applied through water soluble fertilizers *viz*., urea for nitrogen and 0:0:50 for potassium in different calculated proportions through venturi system in 6 equal splits at an interval of 9 days starting at 3-leaf stage of crop. In 'recommended practice', 50:45:75 kg NPK/ha was applied as basal at the time of sowing through urea, SSP and MOP.

'Palam Priya' cultivar of garden pea was sown in October at 40 cm x 8 cm spacing in 4.96 m x 2 m (9.92 m^2) plots. The seeds were pre-soaked in water overnight before sowing. Observations on productivity and water use were recorded every year. Yield attributes were recorded during r*abi* 2012-13. Economics of treatments was worked out based on the prevalent market prices of inputs and output.

Results and Discussion

Conventional Fertilizer application v/s fertigation

During first year, fertigation with micro-sprinkler resulted in 56.05% water saving and statistically similar pea pod yield and gross return as in case of recommended fertilizer application under conventional irrigation system (Table 1 & 2). Owing to huge amount of water saved fertigation resulted in 2.41 times higher WUE than the general practice of applying fertilizers. On the contrary, fertigation with micro-sprinklers resulted in significantly lower net return (18.84%) and B: C ratio (43.03%) than recommended practice mainly due to the higher cost of cultivation in former treatment.

During second and third and thereby on pooled basis, irrigation and fertigation with micro-sprinkler led to less use of water (66.23, 59.9 and 60.89%) and significantly higher green pod yield (10.75, 30.05 and 10.02%). Consequently, water use efficiency was significantly increased (3.67, 3.59 and 3.12 times) as compared to recommended practices (Table 1). Significant increase in green pod yield due to fertigation with micro-sprinkler was reflected in gross return (Table 2), which was also increased by 10.84 and 30.04% during second and third year, respectively. On an average, fertigation increased WUE by 11.59% over the conventional method of fertilizer and irrigation application. Kumar *et al*. (2015) also reported significant improvement in WUE with improved practices in blackgram.

In spite of statistically similar net return, B: C ratio was significantly lower (29.05 and 29.78%) in fertigation with micro-sprinklers than recommended practice during second year and on mean basis (Table 2). During third year, fertigation with micro-sprinklers though resulted in significantly higher net return (25.27%) than recommended practice but had significantly lower B:C ratio (10.05%).

The increase in green pod yield with fertigation may be due to improvement in yield attributes in response to better availability of moisture and nutrients during crop growth. The same is depicted by significant improvement in green pod yield through significant improvement in plants meter^{-1} row length, pods plant^{-1}, pod weight plant^{-1} by fertigation during *rabi*, 2012-13 (Table 3). Rajput and Patel (2012), Kakhandaki *et al.* (2013) and Kumar *et al.* (2013) also recorded similar increase in crop yield by micro-irrigation as compared to irrigation with conventional method. Ramulu *et al*. (2010), Prabhakar *et al.* (2011) and Sayed and Bedaiwy (2011) reported fertigation to produce more yield as compared to conventional fertilizers.

Irrigation scheduling (depth of irrigation)

Irrigation scheduling (depth of irrigation) significantly influenced green pod yield, water use efficiency, gross and net returns and BC ratio during all the years (Table 1 and 2). Increase in irrigation depth resulted in progressive increase in green pod yield, gross returns, net returns and

Table 1. Effect of different treatments on productivity, irrigation water used and water use efficiency of green pea

Treatment	Pod yield (Mg/ha)				IWU (m^3/ha)				WUE (kg/m^3)			
	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled
Control v/s others												
Control	10.65	8.09	7.32	8.68	6,000(12)*	6500(13)	6000 (12)	6167(12)	1.78	1.24	1.22	1.41
Others	10.17	8.96	9.52	9.55	2,637(28)	2195(27)	2406 (28)	2412(28)	4.29	4.55	4.38	4.40
LSD (P = 0.05)	NS	0.29	0.34	0.43	-	-	-	-	0.46	0.17	0.19	0.20
Irrigation schedule (depth of irrigation)												
CPE = 0.4	9.75	8.53	8.63	8.97	1,507(28)	1254(27)	1375(28)	1379(28)	6.47	6.80	6.27	6.51
CPE = 0.6	9.88	8.94	9.56	9.46	2,260 (28)	1881(27)	2062(28)	2068(28)	4.37	4.75	4.64	4.57
CPE = 0.8	11.32	9.79	11.17	10.76	3,013(28)	2508(27)	2750(28)	2757(28)	3.76	3.90	4.06	3.90
CPE = 1.0	9.72	8.60	8.71	9.01	3,767(28)	3135(27)	3437(28)	3446(28)	2.58	2.74	2.53	2.61
LSD (P = 0.05)	1.10	0.27	0.32	0.40					0.44	0.16	0.17	0.19
NK fertigation												
50 % RDF	10.06	9.02	9.44	9.51	2,637(28)	2195(27)	2406(28)	2412(28)	4.15	4.56	4.35	4.34
100 % RDF	10.27	8.90	9.59	9.59	2,637(28)	2195(27)	2406(28)	2412(28)	4.43	4.54	4.40	4.45
LSD (P = 0.05)	NS	NS	NS	NS	-	-	-	-	NS	NS	NS	NS

***** Value in the parenthesis indicate number of irrigations

Table 2. Effect of different treatments on economics of green pea

Treatment	Gross return (INR/ha)				Net return (INR/ha)				B:C ratio			
	2011-12	2012-13	2013-14	Mean*	2011-12	2012-13	2013-14	Mean*	2011-12	2012-13	2013-14	Mean*
Control v/s others												
Control	1,59,750	1,61,733	1,46,333	1,55,939	1,23,195	114323	98,923	1,12,147	3.37	2.41	2.09	2.62
Others	1,52,500	1,79,263	1,90,292	1,74,018	99,980	112894	1,23,923	1,12,265	1.92	1.71	1.88	1.84
LSD (P = 0.05)	NS	5,770	6,857	6,647	17517	NS	6,857	NS	0.34	0.09	0.10	0.12
Irrigation schedule (depth of irrigation)												
CPE = 0.4	1,46,250	1,70,667	1,72,500	1,63,139	93,730	104298	1,06,131	1,01,386	1.77	1.58	1.61	1.66
CPE = 0.6	1,48,250	1,78,700	1,91,167	1,72,706	95,730	112331	1,24,798	1,10,953	1.85	1.70	1.89	1.82
CPE = 0.8	1,69,750	1,95,700	2,23,333	1,96,261	1,17,230	129331	1,56,964	1,34,508	2.25	1.97	2.38	2.20
CPE = 1.0	1,45,750	1,71,983	1,74,167	1,63,967	93,230	105614	1,07,798	1,02,214	1.81	1.60	1.63	1.68
LSD (P = 0.05)	16,515	5,440	6,465	6,267	16515	5440	6,465	6,267	0.32	0.08	0.10	0.12
NK fertigation												
50 % RDF	1,50,938	1,80,433	1,88,833	1,73,401	1,02,548	118582	1,26,982	1,16,037	2.12	1.92	2.05	2.03
100 % RDF	1,54,063	1,78,092	1,91,750	1,74,635	97,413	107205	1,20,863	1,08,493	1.72	1.51	1.71	1.65
LSD (P = 0.05)	NS	NS	NS	NS	NS	3847	4,571	4,431	0.23	0.06	0.07	0.08

*Based on prices prevailing in 2013-14

B:C ratio up to 0.8 CPE. However, increases in green pod yield, gross return, net return and B:C ratio with increase in irrigation depth from 0.4 to 0.6 CPE were not significant during first year (Table 1 and 2). Irrigation every fifth day with 80% CPE (0.8 CPE) resulted in significantly higher green pod yield than every fifth day irrigation with either 60% CPE (14.57, 9.51, 16.84 & 13.74 %) or 40% CPE (16.10, 14.77, 29.43 & 19.96%). This progressive increase in green pod yield with increase in irrigation depth may be due to progressive increase in yield attributes as indicated by observations made during second year of study, where, plants/meter row length, pods/plant, pod weight plant attributed to progressive increase in green pod yield (Table 3). Sarkar *et al*. (2008) also reported progressive and significant increase in bulb yield of garlic with increase in pan evaporation factor. Results are in conformity with Hundal *et al*. (2003) and Kadam *et al*. (2005), Kassab *et al*. (2012) and Patel *et al*. (2012).

During first, second and third year as well as on mean basis, with increase in irrigation depth to 0.8 CPE from 0.6 CPE, the respective increase in gross return was 14.50, 9.51, 16.83 & 13.64%; in net return 22.46, 15.13, 25.77 & 20.82% and in BC ratio 21.62, 15.88, 24.89 & 21.23%. Increase in irrigation depth also resulted in significant and progressive decrease in WUE in all the years due to progressive increase in irrigation water used. Irrigation with minimum depth of water (CPE 0.4) resulted in maximum water use efficiency of 6.47, 6.80, 6.27 and 6.51 kg green pods/m^3 of irrigation water used (IWU) (Table 1).

NK fertigation

Fertigation of sprinkler irrigated crop either with 50 or 100% of recommended soil-test based NK had no effect on green pod yield, gross return and water use efficiency in all the years. It is may be due to improvement of nutrient use efficiency. Teixeira *et al*. (2011) also reported 36% increase in nutrient use efficiency with NK fertigation as compared to conventional fertilization. NK fertigation did not significantly affect green pod weight/plant, shelling percentage and seed weight/pod during *rab*i 2012-13 (Table 3). Fertigation with 50% of recommended NK resulted in higher net return (5.27, 10.61, 5.06 & 6.95%) and B: C ratio (23.25, 27.15, 19.88 & 23.03%) than fertigation with 100% of recommended NK; however, difference in net return was not significant during the first year (Table 1 and 2). Since NK fertigation had no significant effect on green pod yield that mean NK fertigation can be safely reduced to half without sacrificing green pod yield. It is may be due to improvement of nutrient use efficiency.

Table 3. Effect of irrigation depth and NK fertigation on yield attributes and green pod yield of pea

Treatment	Plants/ m row length (cm)	Pods/plant	Pod weight/ plant (g)	Shelling (%)	Seed weight/pod (g)	Green pod yield (Mg/ ha)
Control v/s others						
Control	8.41	21.44	92.08	40.17	5.03	8.09
Others	8.71	23.57	94.88	43.31	5.62	8.96
LSD (P=0.05)	0.27	0.85	2.71	2.01	0.43	0.28
Irrigation depth						
0.4 CPE	8.55	22.40	92.79	41.46	5.25	8.53
0.6 CPE	8.71	24.00	95.93	44.42	5.68	8.94
0.8 CPE	8.97	24.56	97.06	45.44	6.21	9.79
1.0 CPE	8.60	23.33	93.75	41.94	5.35	8.60
LSD (P=0.05)	0.25	0.80	2.55	1.89	0.40	0.26
NK fertigation						
50% of Rec.	8.68	23.28	94.60	43.11	5.59	9.02
100% of Rec.	8.73	23.86	95.16	43.52	5.66	8.90
LSD (P=0.05)	NS	0.57	NS	NS	NS	NS

Conclusively it may be inferred that for saving irrigation water (about 40%) and increasing productivity as well as WUE, garden pea should be fertigated with micro-sprinklers as compared to recommended practices of surface irrigation and fertilization. For maximizing production and economics micro-sprinkler irrigated pea crop should be irrigated every fifth day with water depth of 0.8 cumulative pan evaporation. For obtaining higher net returns and B: C ratio, pea crop should be fertigated with 50% of recommended NK. Irrigation with minimum depth of water (CPE 0.4) resulted in maximum water use efficiency of 6.51 kg green pods/m^3 of irrigation water used.

References

Anonymous. 2010. Annual Report. Department of Soil Science and Water Management. Y S Paramar University of Horticulture and Forestry, Solan (HP).

Anonymous. 2011. Indian Horticulture Database. National horticultural Board, Ministry of Agriculture, Government of India: 174.

Anonymous. 2012. Economic Survey of Himachal Pradesh 2011-12. Economics and Statistics Department: 45

Guidoboni G. 2006. Agronomic benefits of sprinkler irrigation. Information Agrario **62**: 62-65.

Hundal SS, Dhaliwal LK and Kaur P. 2003. Evaluation of water production functions of wheat (*Triticum aestivum* L.) using a line source sprinkler technique. Journal of Research, Punjab Agricultural University **40**: 183-186.

Kadam US, Gorantiwar SD, Kadam SA, Gurav GB and Patil HM. 2005. Effect of different moisture regimes on yield potential of onion (*Allium cepa* L.) under micro-sprinkler irrigation system. Drainage and Irrigation Water Management: 276-286.

Kakhandaki SH, Padmakumari O, Patil RH. 2013. Performance of drip and micro sprinkler irrigation systems in tomato crop. *Karnataka Journal of Agricultural Sciences* **26**: 419-420.

Kassab OM, Ellil AAA, Abdallah EF and Ibrahim MM. 2012. Performance of some chickpea cultivars under sprinkler irrigation treatments in sandy soil. *Australian Journal of Basic and Applied Sciences* **6**: 618-625.

Kumar S, Balaguravaiah D, Ramulu V, Rao CHS. 2013. Comparative efficiency of sprinkler irrigation over check basin irrigation in groundnut at different irrigation schedules. *International Journal of Plant, Animal and Environmental Sciences* **3**: 9-13.

Kumar S, Choubey AK and Singh R. 2015. Analysis of yield gaps in blackgram (*Vigna mungo*) in district Bilaspur of Himachal Pradesh. Himachal Journal of Agricultural Research **41**(1): 49-54.

Patel DK, Patel BM, Patel PT, Patel DM and Patel BJ. 2012. Influence of irrigation methods along with nitrogen and potash management on yield and nutrient uptake by potato. Agricultural Science Digest **32**: 38-42

Prabhakar M, Hebbar SS and Nair AK. 2011. Effect of micro sprinkler fertigation on growth and yield of *rabi* onion. Journal of Horticultural Sciences **6**: 66-68.

Rajput TBS and Patel N 2012. Potential of micro-irrigation for enhancing the water productivity in field crops in India: An overview. Indian Journal of Agronomy **57**: 186-194.

Ramulu V, Reddy MD, Rao AM. 2010. Response of *rabi* maize to irrigation schedules and fertigation levels. Agricultural Science Digest **30**: 104-106.

Sarkar S, Goswami SB, Mallick S and Nanda MK. 2008. Different indices to characterize water use pattern of micro-sprinkler irrigated onion (*Allium cepa* L.). Agricultural Water Management **95**: 625-632.

Sayed MA and Bedaiwy MNA. 2011. Effect of controlled sprinkler chemigation on wheat crop in a sandy soil. Soil and Water Research **6**: 61-72.

Singh B, Singh R and Singh R. 2012. Improving Water and Nutrient Use Efficiency through Fertigation. Indian journal of Fertilizers **8**: 94-103.

Teixeira LAJ, Quaggio JA and Mellis EV. 2011. Enhancing nutrient use efficiency in banana due to irrigation and fertigation. Revista Brasileira de Fruticultura **33** (1): 272-278.

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Influence of weather parameters on occurrence of rice blast in mid hills of Himachal Pradesh

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Abstract

Rice blast, caused by the fungus *Magnaporthe grisea* Sacc. is one of the most important rice diseases found throughout the globe. It usually damages leaves and panicles and reduces the photosynthetic area of the plant and may even lead to the death of the plant. However the disease does not develop until the favorable weather conditions prevail. Present work was undertaken to study the influence of weather parameters on rice blast in mid hill conditions of Himachal Pradesh. Field experiments were conducted during 1984 to 2012 at Palampur, located in mid hills of the Himachal Pradesh. Two varieties; Hasan Sarai and China 988 were sown on two dates (5^{th} and 15^{th} June) under upland irrigated situation. The first leaf symptoms of the disease appeared in the last week of July or the first week of August, when the mid-tillering stage synchronized with favourable weather conditions during all the years. It was observed that days with minimum temperature ≤ 20 ^{o}C, rainfall and cloud cover were important for the appearance and progress of this disease. During disease incidence, period of lower night temperature (19.1 ^{o}C), more number of days with minimum temperature ≤ 20 ^{o}C (11 days) and lower rainfall (246.6 mm) and more cloud amount (135 hrs) was observed during blast years as compared to non-blast years. It was also found that the maximum and mean temperature one week prior to disease appearance was 1.8 and 1.2 ^{o}C lower than the non-blast years indicating warmer temperature during the entire rice growing season is responsible for lower disease incidence and its further progress.

Key words: Rice blast, *Magnaporthe grisea*, minimum temperature, rainfall, cloud cover, disease incidence

Rice blast, caused by the fungus *M. grisea* is the most important of all rice diseases and is distributed throughout the globe. It can damage any aerial organ of rice plant and the plants get the highest disease at maximum tillering stage (Padmanabhan 1965). Leaf infection reduces the photosynthetic area of the plant and may even lead to its death. The panicle infection however causes severe yield losses inflicting the greatest economic injury (Roumen 1992). Losses due to blast may range up to 90% depending upon the part of plant infected (Prabhu *et al*. 2003; Ahmad *et al*. 2011). The climate has a strong influence on the appearance of blast epidemics or its absence altogether even if the sufficient inoculum is present (Suzuki 1975). Lower minimum temperature and cloud cover have been reported to be closely associated with the disease (Padmanabhan *et al*. 1971; Prasad and Rana 2002). Since the weather is clearly an important factor in the variability of disease development, present work was undertaken to study the influence of weather parameters on rice blast in mid hill conditions of Himachal Pradesh.

Materials and Methods

Field experiments were conducted during 1984 to 2012 in randomized block design with 4.5 m x 3 m plot size at CSK HPKV, farm, Palampur, located in mid hills of the Himachal Pradesh under direct seeded and upland irrigated conditions. Variable crop growing environments under field situation were created by two dates (5^{th} and 15^{th} June) of sowing. Two varieties; Hasan Sarai and China 988 were taken for study under two different fertility levels; 10 t/ha

(FYM) + 40 kg/ha of each N, P, and K (farmers' practice) and 10 t/ha (FYM) + 120 kg/ha N (higher dose), 40 kg/ha of each P and K. All recommended agronomical practices were followed to raise the crop. Ten plants were randomly selected from each plot and tagged. Disease scoring was made on the tagged plants at different growth stages; tillering, booting, and flowering for leaf blast by following Standard Evaluation System (IRRI 1996). Daily weather data on maximum, minimum temperatures, rainfall, humidity and cloud cover were collected from agro meteorological observatory of the university. From these weather parameters, mean maximum and minimum temperature, days with ≤20 minimum temperatures, rainfall, rainy and days with >90% humidity and cloud cover were computed. Data on weather parameters was calculated for three periods, one week before incidence, during the incidence and for the complete *kharif* season. To assess the weather condition during blast and non blast years, out of total years, the years were referred as blast years when disease appeared in severe form up to 5-7 scales in districts Kangra and Mandi. The detail of the individual years is given below:

Particulars	Year
Blast years	1984 and 1992
Non blast years	1985-1991 and 1993-2012

Historical weather data temperature, relative humidity, rainy days, cumulative daytime cloud cover, days with relative humidity > 90% and days with minimum temperature ≤ 20 ^{o}C for the past 29 years (1984 to 2012) during rice growing period were analyzed in relation to blast and non- blast years. The weather during disease incidence and disease development phases was then averaged.

Results and Discussion

Weather during disease incidence period during blast and non blast years

During incidence period of individual blast years' (1984 and 1992) the maximum, minimum and mean temperature varied between 25.1-26.7, 18.2-20.0 and 21.7 -23.4^{o}C. Rainfall 161.6- 331.6 mm, cloud cover 124.3-146.6 hours, 8-9 days with RH >90% and 7-11 days with minimum temperature ≤ 20 ^{o}C were observed (Table 1). Lower night temperature, more number of days with minimum temperature ≤ 20 ^{o}C and considerable differences were observed between rainfall (32.3 mm less) and cloud amount (9 hours more) during disease incidence period of blast as compared to non-blast years (Table 2).

Persistence of cloudy days followed by clear nights with no rainfall favours nocturnal cooling and gives rise to copious dew fall. For proper growth of mycelium a thin film of water either from rain or dew for a prolonged period is necessary for disease incidence and further spread. It was observed that minimum temperature along with days with minimum temperature ≤ 20 ^{o}C, rainfall and cloud cover was all together important for the appearance and spread of blast. Absence of even a single favorable parameter leads to the absence or less incidence and spread of the disease. If one of them was not favorable, the disease will either not appear or spread further. Low night temperature is reported to cause partial breakdown of resistance and cause disease (Manibhushanro and Day 1972; Prasad and Rana 2002). Occurrence of temperature of 20 to 24 ^{o}C and relative humidity of 90% had been reported to be favorable for the blast development (Padmanabhan 1953). It was observed that numbers of days with minimum temperature ≤ 20 ^{o}C were more important than other weather parameters. More the number of days experienced the minimum temperature below ≤ 20 ^{o} C higher will be the disease as seen that in blast years, number of days with minimum temperature ≤ 20 ^{o}C were more as compared to non blast year.

Depending upon the prevailing weather conditions the first leaf symptoms of disease appeared generally between the last week of July to the first week of August, when the crop was in the mid-tillering stage during 2004 to 2012 (Table 3).

Temperature during one week before incidence in blast and non- blast years

Since date of disease incidence was variable every year, maximum, minimum and mean temperature one week before disease incidence as an important predisposing weather parameter for both blast and non-blast years was also analyzed. The average values are presented in Table 4. It was found that the maximum and mean temperature one week before disease incidence was 24.5 and 21.8 ^{o} C i.e., 1.8 and 1.2 ^{o}C lower than the non -blast years. Temperature influenced both penetration and establishment phases and partially appeared to be more critical at 25 ^{o}C (Kaur *et al*. 1977). It was observed that resistance to blast is governed not only by genetic factors but also by a set of very critical environment factors including night temperature to a large extent (Sadsivan *et al*. 1971; Chakrabarti 1971).

Temperature during disease development phase during blast and non blast years

There were no perceptible differences in maximum, minimum and mean temperature during blast and non - blast years during the disease development phase (Table 4).

Table 1. Weather parameters during individual rice blast years during disease incidence period (25th July- 5th Aug)

Year	Max (°C)	Min (°C)	Mean (°C)	RH (%)	Rainfall (mm)	Rainy days	Cloud (hrs)	Days RH >90%	Days with minimum temperature ≤ 20 °C
1984	26.7	20.0	23.4	85	161.6	11	124.3	9	7
1992	25.1	18.2	21.7	82	331.6	11	146.6	8	11

Table 2. Weather parameters during disease incidence period (25th July- 5th Aug)

Particular	Max (°C)	Min (°C)	Mean (°C)	RH (%)	Rainfall (mm)	Rainy days	Cloud (hrs)	Days RH >90%	Days with minimum temperature ≤ 20 °C
Blast year	25.9	19.1	21.5	54	246.6	11	135	9	9
Non blast year	26.0	20.0	23.1	84	278.9	10	126	7	7`

Table 3. Date of the disease appearance and development phase duration

Year	Date of Disease incidence	Disease development phase
2004	25th July	25th July-30th August
2005	5th August	5th -29th August
2006	28th July	28th July- 31st August
2007	31st July	31st July-26th August
2008	1st August	1st- 29th August
2009	3rd August	3rd – 31st August
2010	2nd August	2nd - 30th August
2011	22nd July	22nd July- 23rd August
2012	27th July	27th July -30th August

Table 4. Temperature during disease incidence and development phases

Particular	Temperature (°C) during one week before disease incidence phase			Temperature (°C) during disease development phase		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Blast year	24.5	19.1	21.8	25.8	19.4	22.6
Non blast year	26.3	19.7	23.0	26.0	19.4	22.8

Weather during Kharif season in blast and non- blast years

During individual blast year, maximum, minimum and mean temperature varied between 25.5-25.9, 18.8-19.7 and 22.2-22.8 ^{o}C. Rainfall 1517-1827 mm, cloud cover 745-697 hours, days with RH >90% 12-47 and days with minimum temperature ≤ 20 ^{o}C 54-59 were observed. Lower day and night temperature and higher rainfall and cloud amount in the season was observed during blast as compared to non -blast years (Table 5). Besides minimum temperature, higher rainfall and more cloud cover was associated with blast incidences. Minimum temperature and humidity of 95% and above for week or more during susceptible phase of crop was found to be associated with the blast epidemic (Padmanabhan *et al*. 1971). The mean maximum and minimum temperatures, mean morning and evening relative humidity, and rainy days per week were also reported to be critical in mid hills of Himachal Pradesh by Kapoor and Kaundal (2007).

The main point emanated from the study indicates that warmer temperature during disease incidence and during the season as a whole was responsible for lower disease incidence and further progress. In our earlier studies it has already been established that lower minimum temperature of 18-20 ^{o}C was responsible for the disease during the tillering stage of rice crop (Anonymous 2012). Incidence and further build up of the disease was the subject of favorable weather parameters and not by date of sowing however higher dose of nitrogen caused higher disease (particularly neck blast) in variety Hasan Sarai. Favourable thermal regime and higher dose of nitrogen had however the supplementary effect.

Conclusion

Lower day (24.2 ^{o}C) and night (18.7 ^{o}C) temperature, higher rainfall (136.7 mm more) and cloud amount (25 hrs more) were observed during disease incidence period of blast years as compared to non-blast years. The maximum and mean temperature one week before disease incidence was 24.5 and 21.8 ^{o}C, respectively which is 1.8 and 1.2 ^{o}C lower than the non-blast years. It indicates that warmer temperature during disease incidence and during the season is responsible for lower disease incidence and further progress.

Table 5. Weather parameters during *kharif* season (25th June-7th September)

Particular	Max (^{o}C)	Min (^{o}C)	Mean (^{o}C)	RH (%)	Rainfall (mm)	Rainy days	Cloud (hrs)	Days RH >90%	Days with minimum temperature ≤ 20 ^{o}C
Blast year	25.8	19.1	22.5	79.3	1674.7	48.0	701.0	28.7	57
Non blast year	26.7	19. 6	23.1	79.7	1365.0	53.8	643.1	29.41	45

References

Ahmad SG, Garg VK, Pandit AK, Anwar A and Aijaz S 2011. Disease incidence of paddy seedlings in relation to environmental factors under temperate agroclimatic conditions of Kashmir valley. J. Res. Develop. **2**: 29-38.

Anonymous 2012. *Kharif* season annual progress report of All India Coordinated Research Project on Agrometeorology, Palampur Centre, Himachal Pradesh. p 24.

Chakrabarti NK 1971. Relationship between meteorological factors on the development of blast. Oryzae (suppl) **8** (2): 592-597.

IRRI (International Rice Research Institute) 1996. Standard evaluation system for rice. 4th edition, Philippines. p 52.

Kaur S, Kaur P and Padmanabhan SY 1997. Influence of temperature on the develoment of blast in rice. Indian Phytopathol. **30**: 544-546.

Manibhushanro K and Day PR 1972. Low night temperature and blast disease development on rice. Phytopathology **62**: 1005-1007.

Padmanabhan SY 1965. Estimating losses from rice blast in India. In: The rice blast disease. Baltimore, Maryland. Johns Hopkins Press. pp 201-203.

Padmanabhan SY 1953. Effect of nitrogenous fertilization upon the sucsceptibilty of rice blast on rice varities. Curr. Sci. **22**: 271-272.

Padmanabhan SY, Chakrabarti NK and Rao KVSRK 1971. Forecasting and control of rice disease. Proc. Indian Acad. Sci. **37**: 423-429.

Prabhu AS, Filippi MC and Zimmermann FJP 2003. Cultivar response to fungicide application in relation to rice blast control, productivity and sustainability. Pesq. Agropec. Bras. **38**: 11-17.

Prasad R and Rana RS 2002.Weather relation of rice blast in mid hills of Himachal Pradesh. J. Agromet. **4**(2): 149-152.

Kapoor AS and Kaundal R 2007. Development of weather based forewarning systems for rice blast. Him. J. Agri. Res. **33** (2): 211-217.

Roumen EC, 1992. Partial resistance to neck blast influenced by stage of panicle development and rice genotype. Euphytica **64**: 173-182.

Sadsivan TS, Suryanarayanan S and Ramkrishna L 1965. Influence of temperature on rice blast disease. Johns Hopkins Press, Baltomore, Maryland, pp 163-171.

Suzuki H 1975. Meteorological factors in the epidemiology of rice blast. Ann. Rev. Phytopathol. **13**: 239-256.

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Studies on gene action in relation to yield and quality traits in cauliflower (*Brassica oleracea* var. *botrytis* L.)

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Abstract

The present investigation was carried out at Palampur during *rabi* 2012 and 2013 to gather information on the nature of gene action by following line × tester mating design involving five lines and three testers. The analysis of variance revealed significant differences among treatments for days to marketable curd maturity from date of transplanting, gross weight per plant, marketable yield per plant, curd size index, curd depth, curd diameter, per cent marketable curds, stalk length, number of leaves per plant, plant height, harvest index, ascorbic acid content and total soluble solids. The magnitude of dominance variance was higher than additive variance for all the traits except curd depth and total soluble solids which indicated the involvement of non-additive gene action which could be utilized through the development of hybrids in cauliflower. A complete correspondence was noticed between per cent contribution of line × tester interaction (crosses) and non-additive gene action (σ^2D), which reaffirm the importance of hybrids in cauliflower.

Key words: Cauliflower, gene action, GCA variance, SCA variance and line × tester

Cauliflower (*Brassica oleracea* var. *botrytis* L.) (2n=2x=18) belongs to the cole group of vegetables. It was probably originated in the island of Cyprus from where it moved to other areas like Syria, Turkey, Egypt, Italy, Spain and north-western Europe. Syria is considered to be the place of origin for cauliflower. It is one of the important winter vegetables grown throughout India. Today among cole crops, it occupies the pride place in India due to its delicious taste, flavour and being nutritive. It has been rightly described as aristocrat of vegetables. It is grown for its white tender curd commonly used as a vegetable, in curry, soup and for pickling. Cauliflower is a low-calorie food with good dietary fiber, abundant in vitamins (C, B, A, K) and minerals like phosphorus, potassium, calcium, sodium, iron, manganese, magnesium and molybdenum. The leading cauliflower producing countries in the world are China, India, Spain, Italy and France. India is the second major cauliflower producing country after China in the world and contributes 32 per cent in area and 36 per cent in the world production share.

In India, cauliflower is cultivated in an area of 4,04,200 ha with the production of 78,86,700 metric tonnes and its productivity is 19.6 metric tonnes/ ha (Anonymous, 2013), but its potential productivity is 35-40 metric tonnes/ha and maximum productivity of 45.25 metric tonnes/ha has been achieved in New Zealand. In the country, area under hybrids in cauliflower is low as compared to open pollinated and unknown varieties. Thus, for increasing its production and productivity at par with advanced countries, development of hybrids is need of the hour. Hybrids are preferred over the open pollinated varieties on account of their uniform maturity, higher yield and better adaptability under adverse growing conditions. At present, the farmers are purchasing hybrid seeds from the private firms at exorbitant rates. To tide over the situation, there is a need to make concerted efforts to develop quality F_1 hybrids with better productivity and adaptability so as to make available their seeds to the farmers at a reasonable price.

An understanding of the gene action is a pre-requisite for any successful plant breeding programme. In order to exploit different types of gene actions present in the population, information regarding relative magnitude of genetic variances is essential. Investigation was undertaken with the objectives of gaining knowledge on these aspects. Among the different biometrical methods available to determine the genetic information, the "Line × Tester" mating design as proposed by Kempthorne (1957) gives comparable estimate of the genetic make-up of genotypes. The mating design is useful to identify the best general combiners and specific cross combinations amongst a large number of parent lines by attempting relatively less number of crosses as compared to other mating designs.

Materials and methods

In the present investigation, experimental material comprised parents and 15 F_1s produced during *rabi* 2012 by crossing five diverse lines *viz.*, DPCaY-2, DPCaY-3, DPCaY-5, DPCaY-6 and DPCaY-9 with three testers, namely DPCaY-4, DPCaY-8 and Palam Uphar. Variety Palam Uphar (standard check-1) and Hybrid Madhuri (standard check-2) were used as standard checks. The experiment was laid out in randomized block design with 3 replications at Palampur during *rabi* 2013. The spacing between and within rows was 60 and 45 cm, respectively. The observations were recorded on 10 competitive plants in each entrty/replication. The characters studied were days to marketable curd maturity from date of transplanting, gross weight per plant, marketable yield per plant, curd size index, curd depth, curd diameter, per cent marketable curds, stalk length, number of leaves per plant, plant height, harvest index, ascorbic acid content and total soluble solids. The data were subjected to estimation of additive and dominance components of variances and per cent contribution of lines, testers and their interactions as per the formulae suggested by Singh and Chaudhary (1977).

Results and Discussion

Analysis of variance

The analysis of variance indicated significant differences among treatments for all the traits namely, days to marketable curd maturity from date of transplanting, gross weight per plant, marketable yield per plant, curd size index, curd depth, curd diameter, per cent marketable curds, stalk length, number of leaves per plant, plant height, harvest index, ascorbic acid content and total soluble solids when tested against mean squares due to error. It implied that there was sufficient genetic variability among the treatments. The variances due to replications were found non-significant for all traits studied except curd depth (Table 1).

Table 1. Analysis of variance for randomized block design

Trait	Source of variation		
	Replication	Treatment	Error
df	2	23	46
Days to marketable curd maturity from date of transplanting	4.17	357.24*	1.54
Gross weight per plant (g)	842.21	38364.16*	953.59
Marketable yield per plant (g)	1830.46	19072.78*	728.38
Curd size index (cm^2)	15.65	521.58*	5.29
Curd depth (cm)	0.56*	1.12*	0.13
Curd diameter (cm)	0.32	7.24*	0.40
Per cent marketable curds	4.95	43.44*	4.36
Stalk length (cm)	0.00008	1.18*	0.05
Number of leaves per plant	0.03	8.31*	0.99
Plant height (cm)	2.49	40.57*	1.49
Harvest index (%)	14.07	19.15*	4.95
Ascorbic acid content (mg/100g)	1.39	217.67*	1.05
Total soluble solids (^{0} Brix)	0.02	0.65*	0.32

* Significant at $P \leq 0.05$

Estimates of genetic components of variance

An important step in a breeding programme is to choose suitable breeding methodology for purposeful management of generated variability which largely depends on the type of gene action in the population for the trait under genetic improvement (Cockerham, 1961; Sprague, 1966). Among the various designs developed for this purpose, line × tester method (Kempthorne, 1957) not only helps in evaluating parents and crosses for combining ability but also provides information on the nature of gene action controlling the traits under consideration. The nature of gene action has been inferred from estimates of GCA and SCA variances. The estimates of general combining ability variances [σ^2GCA (lines), σ^2GCA (testers) and σ^2GCA (average)], specific combining ability variances (σ^2SCA), additive variances (σ^2A), dominance variances (σ^2D) and proportional contribution of lines, testers and their interactions to the total variances are presented in Table 2. The values of σ^2SCA ranged from -0.04 (TSS) to 2641.09 (gross weight), while σ^2GCA (average) ranged from -1.15 (ascorbic acid content) to 456.23 (gross weight/plant).

The testers showed a higher σ^2GCA than the lines for days to marketable curd maturity from date of transplanting, gross weight per plant, marketable yield per plant, curd size index, curd depth, curd diameter, per cent marketable curds, number of leaves per plant and plant height, whereas σ^2GCA due to lines was higher than the σ^2GCA due to the testers for traits, stalk length, harvest index, ascorbic acid content and total soluble solids. This indicates that both testers and lines have more diversity for the respective traits.

The estimates of σ^2SCA were higher as compared to σ^2GCA (average) for days to marketable curd maturity from date of transplanting, gross weight per plant, marketable yield per plant, curd size index, curd diameter, per cent marketable curds, stalk length, number of leaves per plant, plant height, harvest index and ascorbic acid content indicating the pre-dominant role of non-additive gene action governing these traits. For rest of the traits, σ^2GCA was higher than σ^2SCA. The traits in which σ^2SCA was higher than σ^2GCA (average), σ^2D was also higher than σ^2A. The additive gene action was observed for curd depth and total soluble solids as reflected from their higher additive component of variance than the dominant component of variance. The higher magnitude of σ^2D indicated the involvement of non-additive gene action. Low to moderate heritability in narrow sense was observed, which suggested that heterosis breeding could be useful for obtaining higher gains for the traits studied.

Since, non additive gene action for most of the traits has been found to be predominant, heterosis breeding can prove to be an important tool in cauliflower improvement. However, for the traits *viz.,* curd depth and total soluble solids, where additive variance is high, selection can be followed. These results are in close conformity to the findings of Gangopadhayay *et al*. (1997), Garg *et al*. (2003), Singh *et al*. (2005), Jindal and Thakur (2005), Varalakshmi (2009) and Verma and Kalia (2011).

Proportional contribution of lines, testers and their interactions

The proportional contribution of lines ranged from 5.99 (gross weight) to 48.66 per cent (stalk length). The contribution of lines for marketable yield per plant was 13.95 per cent. The proportional contribution of testers ranged from 2.25 (ascorbic acid content) to 86.78 per cent (days to marketable curd maturity from date of transplanting), while contribution of testers for marketable yield per plant was 70.70 per cent. Similarly, the proportional contribution of line × tester interactions ranged from 6.01 (days to marketable curd maturity from date of transplanting) to 69.39 per cent (ascorbic acid content). The contribution of line × tester interactions for marketable curd yield per plant was 13.59 per cent (Table 2).

The contribution of lines was found to be higher than individual contribution of testers and interactions between line × tester for stalk length and total soluble solids. The contribution of testers was found to be higher than individual contribution of lines and line × tester for days to marketable curd maturity from date of transplanting, gross weight per plant, marketable yield per plant, curd size index, curd depth, curd diameter, per cent marketable curds and number of leaves. The contribution of line × tester interactions was found to be higher than individual contribution of lines and testers for plant height, harvest index and ascorbic acid content.

A complete correspondence was noticed between per cent contribution of line × tester interaction (crosses) and non-additive gene action (σ^2D). The results of gene action studies reaffirm the importance of hybrids in cauliflower. The estimates of GCA and SCA variances, additive (σ^2A) and dominant (σ^2D) components of variance and contribution of lines, testers and line × tester interactions revealed that for most of the traits non additive gene action was in preponderance or in appreciable magnitude. Therefore, heterosis breeding will be a better option compared to other approaches . Curd depth and total soluble solids, exhibiting additive gene action suggests the use of selection in segregating populations to develop improved inbred lines.

Table 2. Estimates of genetic components of variance and proportional contribution of lines, testers and their interactions

Trait / Genetic component	Days to marketable curd maturity from date of transplanting	Gross weight per plant (g)	Marketable yield per plant (g)	Curd size index (cm^2)	Curd depth (cm)	Curd diameter (cm)	Marketable curds (%)	Stalk length (cm)	Number of leaves per plant	Plant height (cm)	Harvest index (%)	Ascorbic acid content (mg/100g)	Total soluble solids (^{0}Brix)
σ^2GCA (lines)	3.28	-479.44	248.31	6.08	0.04	0.08	0.44	0.03	0.01	0.11	-0.14	-3.75	0.15
σ^2GCA (testers)	79.77	6597.54	2874.66	147.83	0.23	0.88	12.06	0.02	1.21	1.42	-0.76	-10.74	-0.003
σ^2GCA (average)	6.34	456.23	240.35	11.75	0.02	0.07	0.95	0.005	0.09	0.12	-0.07	-1.15	0.014
σ^2SCA	6.51	2641.09	455.05	19.26	0.003	0.28	1.22	0.02	0.63	4.45	2.73	61.35	-0.04
σ^2A	25.37	1824.91	961.40	47.00	0.08	0.29	3.80	0.02	0.37	0.47	-0.28	-4.62	0.05
σ^2D	26.06	10564.37	1820.20	77.03	0.01	1.10	4.88	0.07	2.52	17.78	10.91	245.43	-0.14
Heritability (narrow sense) %	64.35	23.55	40.47	52.87	46.45	26.19	22.00	19.98	16.01	4.55	-3.26	-3.89	25.52
Genetic advance	5.89	30.19	28.73	7.26	0.29	0.41	6.59	0.09	0.35	0.21	-0.14	-0.62	0.18
Proportional contribution of lines (%)	7.21	5.99	13.95	8.49	19.91	16.50	9.72	48.66	15.49	24.95	30.34	28.36	75.72
Proportional contribution of testers (%)	86.78	70.70	72.46	82.42	68.86	62.12	77.40	25.10	54.41	28.38	2.51	2.25	3.79
Proportional contribution of line × tester interactions (%)	6.01	23.31	13.59	9.09	11.23	21.38	12.88	26.24	30.09	46.67	67.14	69.39	20.48

References

Anonymous 2013. Indian Horticulture Database. National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon, New Delhi.

Cockerham CC 1961. Implication of genetic variances in hybrid breeding programme. Crop Sci. **1**: 47-52.

Gangopadhyay KK, Gill HS and Sharma SR 1997. Heterosis and combining ability studies in early group of Indian cauliflower involving self incompatible lines. Veg. Sci. **24**: 26-28.

Garg N, Lal T and Vashisht VK 2003. Studies on combining ability and gene action in Indian cauliflower (*Brassica oleracea* var. *botrytis* L.). Crop Improv. **30**: 169-176.

Jindal SK and Thakur JC 2005. Genetic architecture of quantitative characters in November maturity cauliflower. Crop Improv. **32**: 92-94.

Kempthorne O 1957. An introduction to Genetic Statistics. John Wiley and Sons, New York, London pp 458-471.

Singh D, Varalakshmi B and Reddy MAN 2005. Combining ability studies in early cauliflower (*Brassica oleracea* var. *botrytis* L.). Indian J. Hort. **62**: 27-32.

Singh RK and Chaudhary BD 1977. Line × Tester analysis. Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, Ludhiana pp 191-200.

Sprague GF 1966. Quantitative genetic in plant improvement. Proceeding of Symposium, The lowa State University, Amesiowa. pp 315-334.

Varalakshmi B 2009. Heterosis and combining ability for yield and its components in early cauliflower. Indian J. Hort. **66**: 198-203.

Verma VK and Kalia P 2011. Combining ability studies in early and mid-maturity CMS based cauliflower lines. Indian J. Hort. **68**: 503-506.

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Genetic variability in biparental progenies of radish (*Raphanus sativus* L.)

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Abstract

Biparental progenies (BIP's) of inter-varietal cross Mino Early White x Pusa Himani (MEW x PH) of radish were developed in F_2 generation by utilizing North Carolina Design –I suggested by Comstock and Robinson (1948 and 1952). The analysis of variance indicated significant differences among the BIP's and F_3 progenies for different horticultural and quality parameters studied indicating the presence of good quantum of variability between BIP's and F_3 progenies. Biparental progenies when compared with F_3 progenies for their overall mean values revealed that former had greater means for most of the characters except leaf weight, leaf length and nitrate content. The biparental progenies resulted in creation of more genetic variability by breakage of both coupling and repulsion phase linkages that conceal the genetic variability in F_2. The phenotypic variability as revealed by the coefficient of variation (%) was greater in BIP progenies than F_3 progenies. The superior performance of biparental and F_3 generations revealed the breakage of undesirable linkages and plateau effect for bringing further improvement in radish.

Key words: Radish, biparental progenies, F_3 progenies, variability studies

Radish (*Raphanus sativus* L.) is an important quick growing, herbaceous root vegetable crop grown for its fresh edible roots throughout the world. It belongs to the family *Brassicaceae* and is probably a native of Europe and Asia. Its different preparations are useful in curing liver and gall bladder problems. Roots are also used for treating urinary complaints and piles (Hazra *et al*. 2013). Inspite of its economic importance, no major strive has so far been made for the improvement of its yield and quality traits. In allogamous crops like radish, the general breeding procedures have been to select desired segregants in the F_2 population, followed by mass selection or combined mass pedigree selection in the subsequent generations.

These methods do not allow growing and testing of large number of plants in F_2 and succeeding generations. These also do not permit repeated inter-crossing required for obtaining desired recombinants better in yield and quality traits. Therefore, conventional breeding methodology is inadequate to create maximum range of useful genetic variability required for switching genetic amelioration endeavour in any crop species for complex character like yield. Inter-mating of randomly selected F_2 plants may overcome these limitations to a considerable extent by accumulating favourable alleles and breaking undesirable linkages. This allows an additional cycle of recombination leading to transgressive segregants. The variability, thus, generated by breaking undesirable linkages can effectively be utilized in the subsequent generations. Biparental mating in early segregating generations would not only help in creating new rare recombinants, but also retain greater variability by breaking tight and unfavourable linkages for selection to be effective for a longer period. Keeping in view the above-mentioned facts, the present investigation based on biparental and F_3 progenies have been undertaken to obtain information on the genetic architecture of root yield and component traits in radish as suggested by Comstock and Robinson (1948 and 1952).

Materials and Methods

The present investigation was carried out at Vegetable Research Farm, CSKHPHV, Palampur (H.P.) in Randomized Block Design (RBD) with three replications for root yield, quality traits and yield contributing components. The experimental material was developed from an inter-varietal cross *viz.*, Mino Early White x Pusa Himani (MEW x PH). The parents were selected based on their genetically diverse origin involving Asiatic and European cultivars.

Biparental progenies were developed in F_2 generations of the inter-varietal cross MEW x PH using North Carolina Design -I as suggested by Comstock and Robinson (1948 and 1952). The biparental progenies were developed by designating four F_2 plants as male parents and crossing each of these to four plants selected as females. The plants used as males and females were chosen at random for the development of bi-parental progenies and no seed parent was used in more than one mating. The plants used in making the biparental progenies were also selfed. Thus, the family consisted of sixteen progenies (four in each male group). Twenty F_3 families were developed by selfing (4 males and 16 females). The experiment comprised three such sets or a total of 48 biparental progenies and 60 F_3 families. The data on BIP's and F_3 progenies were recorded for root yield, yield components and quality parameters (Table 1).

The method of analysis of variance followed was as proposed by Comstock and Robinson (1948 and 1952). The standard errors of s^2m and s^2f were calculated as per formulae proposed by Moll *et al.* (1960), whereas the standard errors of s^2_A and s^2_D were calculated by the method proposed by Panse and Sukhatme (1984). Expected gains from full-sib family selection were calculated as per procedure outlined by Robinson *et al.* (1949).

Results and Discussion

The analysis of variance indicated significant differences among the BIP's and F_3 progenies for different growth, yield and quality traits studied exhibiting the presence of good quantum of variability between BIP's and F_3 progenies.

Biparental progenies when compared with F_3 progenies for their overall mean values, in general, had greater means for most of the characters (except leaf weight, leaf length and nitrate content) which may be due to more heterozygosity in the former (biparental) progenies. The superior performance of biparental families seems to be primarily due to generation of more genetic variability by breakage of both coupling and repulsion phase linkages that conceal the genetic variability in F_2. The study confirms the findings of Dadlani *et al.* (1983), Lal *et al.* (1990) in cauliflower, Singh and Sharma (1983) in okra and Kumar (1997) in brinjal. Superior mean performance of BIP's over F_2 self's would generally be expected when major portion of total genetic variance is additive and additive x additive type. In addition, even dominance and epistatic components could play some role towards increase in the mean of BIP's as compared to F_2 self's. These results corroborate with the findings of Kanwar and Korla (2002) and Kumar (1997) in brinjal.

The comparison of biparental and F_3 progenies for root yield per plant revealed that the mean of BIP's (395.2 g) was significantly higher than F_3 progenies (319.3g) in cross Mino Early White x Pusa Himani (MEW x PH). Significantly higher mean values were also observed in case BIP's for root yield per plot, root weight, root diameter, root: top ratio, days taken to maturity and dry matter content. The 't' ratio for leaf weight was negative and significant in cross Mino Early White x Pusa Himani. This suggests that it could be possible to isolate early transgressive segregants.

As regards the range in mean values for the various characters (Table 1), it was observed that the lower value of the range was less in F_3 progenies compared to BIP's and the higher value was high in BIP's as compared to F_3 progenies in most of the cases. Obviously, the proportion of desirable variants increased in the BIP's, which was also accompanied by an increase in the mean performance as stated earlier. Similar results were also reported by Singh and Sharma (1983) in okra, Dadlani *et al.* (1983) and Kumar (1997) in brinjal and Kanwar and Korla (2002) in cauliflower.

The phenotypic variability as revealed by the coefficient of variation (%), was greater in BIP progenies than F_3 progenies for most of the characters. This may be due to the breakage of both coupling and repulsion phase linkage in BIP's. The superiority of BIP's progenies over F_3 progenies with respect to coefficient of variation has also been reported by Singh and Sharma (1983) in okra. However, exceptions were noted in cross for root yield per plot, root length and root: top ratio where the coefficient of variation was higher in F_3 progenies than BIPs. These results substantiated the findings of Dadlani *et al.* (1983) who had also reported superiority of F_3 progenies over BIP's with respect to coefficient of variation in cauliflower.

The BIP's M_2 x F_8, M_1 x F_{17}, M_1 x F_{18}, M_1 x F_{20}, M_2 x F_{24}, M_3 x F_{42} and M_4 x F_{48} resulted in high mean values for root yield, quality traits and yield contributing components. The outstanding cross combinations were M_1 x F_{18}, M_2 x F_8 and M_1 x F_{17}. These combinations manifested increase in root yield to the extent of 72.74, 60.91, 60.24%, 126.47, 110.95, 110.03% and 34.21, 25.02, 24.50% over the respective parents *viz.*, Mino Early White (MEW), Pusa Himani (PH) and the F_1 produced from them. The increase in

Table 1: Range, mean, standard deviation and coefficient of variation for different traits in biparental (BIP,s) and F_3 progenies in cross Mino Early White x Pusa Himani (MEW x PH)

Trait	Range[@]	Mean		Standard Deviation		Coefficient of variation		[§] t-ratio
		BIP	F_3	BIP	F_3	BIP	F_3	
Root yield (kg/plot[$])	2.7-5.5	3.6	3.2	0.6	0.7	22.0	25.1	3.3**
Root weight (g)	170.6-395.2	234.6	216.5	30.1	38.2	24.9	22.4	2.6*
Root length (cm)	19.5-30.6	24.2	22.6	2.3	2.0	42.8	30.1	4.0**
Root girth (cm)	10.8-16.9	14.7	13.5	1.5	1.9	13.0	16.3	4.8**
Root diameter (cm)	3.2-5.1	3.7	3.6	0.4	0.5	13.4	16.1	0.2
Leaf weight (g)	55.4-75.1	65.1	70.1	11.1	10.7	29.8	24.5	-2.3*
Root : top ratio	2.8-4.3	3.6	3.2	0.6	0.7	21.2	26.7	2.9**
Days taken to maturity	50.4-64.5	59.9	57.9	5.9	4.3	11.9	8.8	2.1*
Leaf length (cm)	20.5-35.2	26.1	27.6	5.3	3.7	22.7	25.6	-1.7
Number of leaves	11.6-25.8	16.2	15.3	5.7	3.8	40.8	29.7	0.9
Total soluble solids (%)	5.5-8.1	7.3	7.11	0.6	0.73	11.0	12.52	1.6
Dry matter (%)	4.5-8.1	7.4	6.49	0.7	1.29	21.3	23.49	4.1**
Ascorbic acid (mg/100g)	14.5-22.0	19.7	19.11	2.0	1.77	12.2	10.90	1.8
Nitrate content (mg/100g)	170.1-216.6	189.3	195.07	20.4	17.19	12.4	9.20	-1.5

[@] The range has been calculated on progeny mean basis and the figures rounded up to the nearest whole number.
[§] t-ratio has been computed for the comparison of biparental (BIP, s) and F_3 progenies.
* Significant at $P < 0.05$. ** Significant at $P < 0.01$. \$ 0.75 m^2

root yield by them was 43.56, 33.73, 33.18% and 24.87, 16.32, 15.84% over F_2 and F_3 generations, respectively.

On comparing the coefficient of variation for various characters, it was observed that comparatively high quantum of phenotypic variability was observed in case of root yield per plot, root weight, root length, leaf weight, root: top ratio and number of leaves. The limited variability for most of the characters, in parents probably resulted in narrow coefficient of variation in BIP's and F_3 progenies. In spite of this narrower variability, the increase in root yield in top 5% BIP's was remarkable as found in the plant breeding comparisons. Top 5% BIP's were superior to their corresponding top 5% F_3 progenies, original parents, F_1's and F_2's progenies. Thus, the BIP's assume importance in the improvement of radish by breaking the plateau effect, which has resulted due to fixation of genes and as such transgressive segregants are feasible in radish through biparental mating which could be utilized for the development of high yielding and quality cultivars of radish.

References

Comstock RE and Robinson HF 1948. The components of genetic variance in population of biparental progenies and their use in estimating the average degree of dominance. Biometrics **4**: 254-266.

Comstock RE and Robinson HF 1952. Estimation of average dominance of genes. In: *Heterosis*, ed Gowen JW, IOWA State College Press, Ames. IOWA, pp 494-516.

Dadlani ND, Swarup V and Chatterjee SS 1983. Studies on biparental progenies in Indian cauliflower. Vegetable Science **10**(1): 112-122.

Hazra P, Chattopadhyay A, Karmakar A and Dutta S 2013 Radish.*In: Modern Technology in Vegetable Production*, New India Publishing Agency, New Delhi, pp 256-266.

Kanwar MS and Korla BN 2002. Performance of Biparental progenies in late cauliflower variability and association analysis. Vegetable Science **29**(1): 13-16.

Kumar P 1997. Genetic analysis of some horticultural traits including bacterial wilt resistance genotypes in brinjal (*Solanum melongena* L.). Ph D (Agri.) Thesis, Faculty of Agriculture, CSKHPKV, Palampur.

Lal T, Chatterjee SS and Swarup V 1990. Evaluation of biparental progenies for the improvement of Indian cauliflower. Vegetable Science **17**(2): 157-166.

Moll RH, Robinson HF and Cockerham CC 1960. Genetic variability in an advanced generation of a cross of two open pollinated varieties of corns. Agronomy Journal **52**: 171-173.

Panse VG and Sukhatme PK 1984. *Statistical methods for Agricultural workers*, ICAR, New Delhi, pp 381.

Robinson HF, Comstock RE and Harvey PH 1949. Estimates of heritability and the degree of dominance in corn. Agronomy Journal **41**: 353-359.

Singh SB and Sharma BR 1983. Relative efficiency of different mating system for improvement of Okra. SABRAO Journal **15**(2): 125-131.

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An exploratory study on production and economics of fishing in Pong Dam wetland of district Kangra

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Abstract

The Pong dam wetland is the largest man made wetland of district Kangra of Himachal Pradesh. This reservoir covers an area of 24,529 ha. The local people adjoining the Pong wetland exploit the wetland for food grain production and fishing. Thus, it provides significant role in their household system. The Department of Fisheries in Himachal Pradesh initiated commercial fishing soon after the emergence of the reservoir. Scanty attempts have been made in the past for estimation of economic benefits accrued from the wetland. The present study was carried out in Pong Dam wetland. The fishing households were randomly selected. The total cost of fish capture was INR 47,427 per fisherman. The fixed cost accounted for 14.44% of total cost. The total variable cost incurred on fishing was INR 40,579/fisherman/annum which accounted for 85.56% of the total cost. The gross income obtained by a fisherman from fishing was INR 96552 per annum. The net return over variable cost and total cost was positive indicating profitability of the fishing to the fishermen. The return on investment was 2.03. Season wise fish catch per fisherman was highest in winter (272.78 kg/fisherman) followed by rainy (163.24 kg/fisherman) and summer (137.61 kg/fisherman). The average production per day was about 2 kg per fisherman. The fishermen share in consumer's rupees was highest (75%) in winter. The per kg expenditure incurred by the contractor for marketing of fish was INR 11/kg. Since the fishing business is adopted by large population, therefore, the royalty and commission charged from the fishermen need to be reduced. The co-operative societies should provide facility of mechanized boating at subsidized rate to enhance the efficiency and income of the fishermen.

Key words: Wetland, fish production, return, return on investment, fishermen share in consumer's rupees

Wetlands are recognized as the most productive ecosystem on the earth for their vital role in sustaining a wide array of bio-diversity and providing goods and services to the society. These support millions of people not only living in their periphery but outside the wetlands as well (Katarina 2008). The Ministry of Environment and Forests, Government of India, has declared at least 21 wetlands of national importance in the country. Out of these, three wetlands- Pong Dam, Renuka and Chandertal are situated in Himachal Pradesh. The state of Himachal Pradesh has 27 natural wetlands covering an area of 15 km^2. Besides, there are 5 manmade wetlands covering an area of 712 km^2. The Pong dam wetland located in district Kangra, is one of the largest man made wetland in Himachal Pradesh. The catchment area of the wetland is 12560 km^2. This reservoir covers an area of 24,529 ha. The wetland portion is 15,662 ha. Pong dam wetland was declared a Ramsar wetland site on account of its rich waterfowl diversity and sustainable use of the wetland. The local people adjoining the Pong wetland exploit it for food grain production and fishing. Therefore, it provides significant role in their household system. The Department of Fisheries in Himachal Pradesh initiated commercial fishing soon after the emergence of the reservoir. The exploitation of wetland is done in common property resources regime. Due to the free ridership of wetlands, the pace of degradation is quite high. Scanty attempts have been made in the past for estimation of economic benefits from this wetland. Therefore, in the present study, an attempt has been made to study returns accrued to sample households from fisheries.

Materials and Methods

The present study was carried out in Pong Dam wetland located in Kangra district of Himachal Pradesh. It was purposively selected to examine the benefits accrued to the farmers of catchment area. Two-stage sampling design was employed for the selection of sample. At first stage eight villages were randomly selected from the Pong dam wetland. At the second stage the sample of ten households was randomly drawn from each selected village. The total sample consists of 80 households. Both primary and secondary data were collected in order to fulfill the specific objectives of the study. The primary data were collected on well designed pre-tested schedule. The study was undertaken during the agriculture year 2014-15. The suitable analytical tools were employed to analyze the data.

Results and Discussion

Fish production and revenue to Government

The fish production, fish value and revenue to the government have been presented in Table 1. It was observed that there was no definite trend in production of fish over the years. The production of fish ranged between 284 tonnes in 2008-09 to 391 tonnes during 2001-02. However the value of fish increased over the years. This may be due to increase in prices of the fish. The Himachal Pradesh government earns income from fishing in the form of royalty, license fee and fish auction. There was increasing trend in the income of state Govt over the years. The total revenue earned by the government increased from INR 30.79 lakhs during 2001-02 to INR 70.60 lakhs during 2013-14 showing an increase of 129.30%.

The percent change in fish catch and revenue over 2001-02 has been presented in Table 2. It was observed that there was no definite trend in the decrease of production over 2001-02. The per cent decrease varied from -27.45 (2008-09) to -21.37 (2013-14). Over the years the value of fish showed an increasing trend upto 2013-14. The value of fish during 2013-14 has increased by 137% over 2001-02. This may be due to increase in the prices of the fish in the market. The total revenue which included royalty, license fee and fish auction fee also showed increasing trend over 2001-02.

Socio-economic characteristics of sampled farms

Socio-economic characteristics of agricultural farmers and fishermen according to gender, age, education and occupation are presented in Table 3. About 53% sampled farms were in the working age group in case of agricultural farmers and 44% in case of fishermen. The average family size was estimated at 6.43 and 5.35, respectively. The literacy rate of the sampled agricultural farmers and fishermen

Table 1. Total fish catch, value and revenue from Pong reservoir

Particular	Year				
	2001-02	2005-06	2008-09	2011-12	2013-14
Total fish catch (t)	390.90	306.40	283.60	286.00	307.36
Value of fish (Lakh INR)	181.81	173.82	201.63	373.00	431.00
Royalty (Lakh INR)	27.31	26.07	30.23	55.91	64.66
License fee (Lakh INR)	1.75	1.75	1.88	2.39	2.62
Fish auctioned & other fees realized (Lakh INR)	1.47	1.54	2.23	2.13	3.29
Total revenue (Lakh INR)	30.79	30.93	35.36	61.93	70.60

Table 2. Per cent change in production value and total revenue over 2001-02

Particular	2005-06	2008-09	2011-12	2013-14
Fish catch	-21.62	-27.45	-26.84	-21.37
Value of fish	-4.39	10.90	105.16	137.06
Total revenue	0.45	14.84	101.14	129.3

was 82.46 and 74.25%, respectively, which was found to be higher among agricultural farmers compared to fishermen. Agricultural farmers (0.5 ha) have higher average size of holdings as compared to fishermen (0.07 ha). Similarly, total number of livestock in terms of standard animal units (SAUs) was found to be higher in agricultural farmers (4.67 SAU) as compared to fishermen (1.31 SAU). The total income of INR 2,92,166 per farm for agricultural farmer was higher than fishermen (INR 1,41,802). The data clearly revealed that the different socio-economic parameters were better for agricultural farmers than fishermen indicating the need for improvement of socio-economic parameters of fishermen. Similar trend was noted from the studies conducted by Balachandran *et al*. (2005) and Kalpana *et al*. (2007).

Table 3. Socio- economic profile of the sample farms

Particular	Agricultural farmer	Fisher-men	Total
Age group (years)			
<15	72	20	92
	(18.60)	(18.69)	(18.62)
15-30	103	38	141
	(26.61)	(35.51)	(28.54)
30-45	109	21	130
	(28.17)	(19.63)	(26.32)
45-60	70	21	91
	(18.09)	(19.63)	(18.42)
Above 60	33	7	40
	(8.53)	(6.54)	(8.10)
Total	387	107	494
	(100.00)	(100.00)	(100.00)
Average family size	6.43	5.35	6.18
Literacy rate (%)	82.46	74.25	80.34
Av. land holding (ha)	0.50	0.07	0.39
Livestock size (SAU)	4.67	1.31	3.84
Income /farm	2,92,166	1,41,802	2,54,575

Figures in parentheses indicate percentage

Benefits from fisheries

Prior to the impoundment of the river Beas, a subsistence fishery of inconsequential nature existed in the river and adjoining streams. The average catch hardly exceeded 2-4 kg per fishermen daily. But with the formation of the reservoir, a lucrative fishery started attracting large number of fishermen, who had no other viable means of livelihood. The fishermen accounted about 30% of the total population of catchment area. The fisheries department initiated training course for operating gears in the deeper waters for fishermen. This, inspired a large number of outsees of various communities to adopt fishing as a profession.

Season wise production

Season-wise fish production has been given in Table 4. The fish catch per fisherman was highest in winter (272.78 kg/fisherman) followed by rainy (163.24 kg/ fisherman) and summer (137.61 kg/fisherman) seasons. The average production per day was about 2 kg per fisherman. The value of fish catch season-wise varied between INR 21,330 to INR 49,919. The total income per fisherman earned during the year was INR 96,552. Chauhan (1995) also reported similar results.

Table 4. Season wise fish production and income of sample fishermen (per fisherman)

Particular	Summer	Winter	Rainy	Total
Fish catch	1.50	1.80	2.67	1.99
Total (kg)	137.6	272.7	163.2	573.6
Income (INR)	21330	49919	25303	96552

Cost and returns from fishing

Cost and returns from fishing are presented in Table 5. The fixed cost was INR 6898, which accounted for 14.44% of the total cost. The variable cost includes labour, repair, royalty and commission. The royalty and commission on fish production was paid to government by fishermen. The labour cost was 74% of the variable cost followed by repairs (14.78%) and commission (7.46%). The total variable cost incurred on fishing was INR 40,579. The gross income obtained by a fisherman from fishing was INR 96, 431 per annum. The net return over variable cost and total cost was positive indicating profitability of the fishing business. The return on investment was 2.03. This showed that fishing in the Pong dam reservoir was a profitable venture.

Table 5. Costs and returns from fishing by sample fishermen (INR/fisherman)

Particular	Value (INR)	Percent-age
A. Total fixed cost		
Depreciation	4748	10.01
Interest on fixed capital 8%	2100	4.43
Sub total	6848	14.44
B. Variable cost		
Repairs of boats and gill nets	6000	12.65
Labour	30000	63.26
Royalty to the government	1549	3.27
Commission to the co-operative society	3030	6.39
Sub total	40579	85.56
C. Total cost	47427	100
D. Gross Income	96431	-
E. Net Income over		
i. Total cost	49004	
ii. Variable cost	55852	-
iii. Returns on investment	2.03	-

Marketing costs, marketing margins and price spread

Table 6 shows that the net price received by the fishermen during summer and winter season was INR 127 and INR 150 per kg of fish, respectively. The fishermen share in consumer's rupees was highest (75%) in winter. The expenses incurred on marketing of fish include commission to co-operative society and fishery department. The amount of expenses on these activities varied from INR 4.65 per kg in summer to INR 27.50 per kg in winter. The contractors selling price at markets was INR 175 and 200 per kg in summer and winter, respectively. The expenses incurred by contractor for marketing of the purchased fish include labour charges for weigh men, transportation, market fees, ice and other charges. The per kg expenditure incurred by the contractor for marketing of fish was INR 11 per kg in both seasons. The higher expenditure was on transportation followed by ice charges.

Conclusion

The total cost of fish capturing was INR 47,427 per fisherman. The gross income per fisherman was INR 96552 per annum. The net return was positive. The return on investment was 2.03. Fish catch was highest in winter. The average production per day was about 2 kg per fisherman. The royalty and commission charged from the fishermen need be reduced. There was need to provide mechanized boats to enhance the efficiency and income of fishermen.

Table 6. Marketing costs, marketing margins and price spread

Functionary	Summer		Winter	
	INR/kg	Per cent of total	INR/kg	Per cent of total
Net price received by the fishermen	127.00	72.50	150.00	75.00
Expenses incurred by fishermen	28.00	16.00	33.00	16.50
i. commission to co- operative society @3%	4.65	2.65	5.50	2.75
ii. commission to fisheries department @15%	23.35	13.34	27.50	13.75
Contractors purchase price	155.00	88.57	183.00	91.50
Expenses incurred by contractor	11.00	6.29	11.00	5.50
i. Ice	2.00	1.14	2.00	1.00
ii. Labour charges for weigh men	1.50	0.86	1.50	0.75
iii.Transportation cost	5.00	2.86	5.00	2.50
iv. Market fees	0.50	0.29	0.50	0.25
v. Misc. charges	2.00	1.14	2.00	1.00
Contractors sale price	175.00	100.00	200.00	100.00

References

Balachandran S, Fernandes M and Deepak S. 2005. A preliminary analysis of the environmental economics of Pong Dam. State Council for Science, Technology & Environment Government of Himachal Pradesh. Bombay Natural History Society.

Chauhan SK. 1995. Economics of production and marketing of reservoir fisheries in Himachal Pradesh. Unpublished Project Report, Department of Agricultural Economics, CSKHPKV, Palampur, India. Pub No. 86.

Kalpana A, Hussain SA and Badola R. 2007. Resource dependence and attitudes of local people toward conservation of Kabartal wetland: a case study from the Indo-Gangetic plains. *Wetlands Ecological Management* 15: 287-302.

Katarina Polajnar. 2008. Public awareness of wetlands and their conservation. *Acta geographica Sloenica* 48: 121 -146

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Occurrence of entomopathogenic fungus, *Beauveria bassiana* (Bals.) on potato whitegrubs in Himachal Pradesh

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Abstract

Survey to isolate and identify the entomopathogenic fungi associated with whitegrubs was conducted in Himachal Pradesh during 2008 and 2009. The whitegrubs were collected from 14 locations and *Beauveria bassiana* (Bals.) was found to be associated with grubs of *Brahmina coriacea* (Hope) in Shillaroo and Kheradhar areas. The fungus infected grubs were observed only in higher hills of Shimla and Sirmour districts. At Shillaroo, 0.98% grubs of *B. coriacea* were observed to have fungal infection, whereas at Kheradhar 20.2% of the grubs showed symptoms of mycosis. When field collected grubs were reared separately location- wise in laboratory, very high percentage of mycosis (55.29%) was recorded. Kheradhar and Shillaroo populations of whitegrubs showed white muscardiane infestation in 8.72 and 5.27% of the grubs, respectively. Conidia of the fungus were globose to subglobose measuring 2.0-3.0×2.0-2.5 µm. Incubation of Shillaroo, Kheradhar, Kharapathar and Solan isolates was done at 20, 22 and 26 °C. After 15 days, the radial growth of Shillaroo isolate of *B. bassiana* was recorded to be 7.66 cm as compared to 7.60, 7.60 and 7.36 cm for Kharapather, Solan and Kheradhar isolates, respectively.

Key words: *Beauveria bassiana, Brahmina coriacea,* entomopathogenic fungi, whitegrubs

Microbes are being exploited as alternatives and complimentary to chemical insecticides for the control of insect -pests. Among the various microbes, entomopathogenic fungi are considered as the best agents for whitegrub management (Chandel *et al.* 2005) because of their regular multiplication due to good moisture available in the soil. There is great diversity of fungus-insect interaction and virtually all insect orders are susceptible to fungal diseases. Rai *et al*. (2014) reported that approximately 750 species of fungi from about 90 genera have been documented to be entomopathogenic. However, only a few of these species are currently being developed as pathogens against insect-pests. Fungi are particularly important for control of Coleoptera, because viral and bacterial diseases are rare in beetles (Hajek and Leger, 1994). The unique character of fungi as compared to bacteria and viruses is that they penetrate through the insect cuticle, thus making them as valuable biological control agents of whitegrubs. In many systems, a reduction in feeding in an infected host is one of the first overt changes. This response provides an often-overlooked benefit of fungal pathogens infecting pest insects. The search for and development of commercially viable entomopathogenic fungi entails several steps including isolation from the host insect, followed by studies on ecology and physiology. In past years, attempts to use fungal entomopathogens for inundative releases, similar to use of synthetic chemical insecticides, have frequently been unsuccessful (Chandel and Mehta 2005; Chandel *et al*. 2005). So now it is realized to harness the potential of local entomopathogenic fungi. The main aim of this study was to advance our knowledge of fungal diseases, in general, and use it further in developing control strategies against whitegrubs by means of local entomopathogenic fungi.

Materials and Methods

Survey for entomopathogenic fungi (EPFs): Soil sampling was done in different parts of Himachal Pradesh. A total of 153 samples from 9 districts representing 14 localities (Table 1) were collected. The samples were taken from different habitats *viz.* potato, ginger, pea, maize, cabbage and fruit orchards. Although sampling was done throughout the year, but most of the samples were taken during July-November. The grubs were collected by digging one cubic feet of soil carefully by shovel and then by searching it by hand for larval, pupal and adult stages. At each site, minimum 5 soil pits were dug. Information regarding location, altitude and total and mycosed grubs was collected for each sample. The infested dead grubs were separated from healthy grubs and brought to the laboratory in individual plastic vials. The healthy grubs were placed in plastic containers in groups of 40-50 with soil from the same collection site.

Isolation and identification of fungi: The diseased grubs showing white mycelial growth on their body were directly used for isolation of fungi. The fugus infected grubs were surface sterilized by immersing them into sodium hypochloride (5%) for two minutes and then rinsed with sterile distilled water thrice under aseptic conditions. Then the sterilized specimen was cut open in a sterile Petri plate and a small portion of infected tissue was streaked on PDA slants; which were incubated at $26\underline{+}1^0$C for further growth. After about 15 days of incubation, the purification of fungal culture was done through streak plate method. A loop full of fungal spores was streaked on PDA in Petri plates under aseptic conditions. These Petri plates were incubated at $26\underline{+}1^0$C for 15-20 days, and after sporulation the fungus was again transferred to PDA slants and maintained in incubator. The identification of fungus was done by preparing the slides of the fungus and the final identification was confirmed at Department of Plant Pathology, CSKHPKV Palampur. The pathogenicity was proved using second instar grubs of *B. coriacea* and Koch's postulates were proved.

Effect of temperature on growth of *B. bassiana*: Four strains of *B. bassiana* isolated from Shillaroo, Kheradhar, Kharapathar and Solan were taken for their growth studies at different temperatures. The growth and development of these four isolates were recorded at 20, 22 and 26 ^{0}C. The PDA medium from the flask was poured into Petri plates and allowed to solidify. Small fungal discs (5 mm diameter) of different isolates were placed in the center of each Petri plate (5 plates for each isolate) and the plates were incubated at 20, 22 and 26 ^{0}C in BOD incubator. Data on radial growth of fungus were recorded at an interval of 5, 10 and 15 days. The statistical analysis was done in Completely Randomized Design using computer based CPCS software.

Results and Discussion

The whitegrubs were collected from 14 different locations of Himachal Pradesh. *B. coriacea* was found to be the predominant species. The fungus infected grubs were collected only in high altitude areas. However, per cent infestation was recorded to be very low. At Shillaroo, population of whitegrubs varied from 6 to 18 grubs/feet^3, however, only 0.98% of the grubs showed mycosis (Table 1). Kheradhar area in Sirmour district was another endemic pocket of whitegrubs and *B. coriacea* was by far the most prevalent whitegrub species encountered in soil sampling from potato fields. At Kheradhar, a total of 321 grubs were collected, out of which 20.2% were found to be infected with the fungus. The dead grubs showed clear cut symptoms of fungal infestations and their body was completely covered with white growth of fungus (Fig. 1). At most other locations none of the collected grubs showed visible symptoms of fungal infestation irrespective of altitude of the area and species of whitegrubs. Farmers resort to frequent application of pesticides like chlorpyriphos, phorate, Ridomil and Diathane M-45 to control various insect-pests and diseases and all these have antagonistic effects against entomopathogenic fungi which seems to be the possible reason for low natural infestation of entomopathogenic fungi in soil arthropods like whitegrubs. When the field collected grubs were reared in laboratory at Palampur, many of the grubs died due to fungal infestation. Among Shillaroo culture, 5.27% of the grubs showed mycosis during rearing in laboratory. Similarly, from Kheradhar 8.72% mycosis was observed under laboratory rearing. In Kharapathar population, 55.29% of the grubs were found dead due to infection. In laboratory, proper soil moisture was maintained through regular watering which provided ideal conditions for growth and conidia production of fungus. Cisneros and Vera (2000) also reported that mycelial growth reactivates in fungus infested specimens when they are exposed to proper moisture conditions.

The data in Table 1 clearly showed that the fungus occurs only in high hill temperate wet zone of Himachal Pradesh. According to Muller-Kogler (1965), the epizootics of fungi are usually associated with period of high humidity particularly, rainy periods. Germination of spores is seriously affected, since most fungi germinate only at very high RH usually 90% or higher. Arthurs and Thomas (2001) reported that the efficacy of fungal entomopathogens is highly dependent on suitable climatic conditions, in particular the availability of a high level of environmental moisture. In case of *B. brongniartii*, high soil moisture (50% FC) favours the development of mycelia outside the infected insect's body, whereas low moisture (25% FC) favours the production of conidia.

Isolation and identification of EPFs from whitegrubs

The fungus was isolated on PDA from field infected

a b

Fig 1. (a) Healthy whitegrubs, and (b) fungal infected whitegrub

Table 1. Natural infection of entomopathogenic fungi in white grubs

Location	Altitude (m amsl)	Sampling field	Predominant species	Total number of grubs collected	Mycosed grubs observed in		Mycosis (%)	
					Field	Lab	Field	Lab
Shillaroo	2450	Potato	*B. coriacea*	815	8	43	0.98	5.27
Kharapathar	2580	Potato	*B. coriacea, Holotrichia* sp.	85	0	47	0	55.29
Kufri	2500	Potato	*B. coriacea*	28	0	0	0	0
Fagu	2650	Potato	*B. coriacea*	105	0	0	0	0
Kheradhar	1950	Potato	*B. coriacea*	321	65	28	20.2	8.72
Kheri	300	Maize	*Lepidiota stigma, A. dimidiata*	73	0	0	0	0
Sangrah	1800	Ginger	*H. longipennis*	23	0	0	0	0
Janjehli	2200	Potato, Peas	*B. flavosericea*	55	0	0	0	0
Baragaon	1835	Potato, Cabbage	*Melolontha* sp.	107	0	2	0	1.86
Seobagh	2100	Fruit orchards	*B. coriacea, B. crinicollis*	61	0	0	0	0
Sangla	2580	Pea	*Melolontha* sp.	12	0	0	0	0
Palampur	1110	Potato, Cabbage	*H. longipennis*	45	0	0	0	0
Phulladhar	2250	Potato	-	0	-	-	-	-
Kamrah	2400	Potato	-	0	-	-	-	-

whitegrubs. After purification, the fungus was identified as *Beauveria bassiana* (Bals.). To test the pathogenicity of collected isolates of *B. bassiana*, the grubs were dipped in a spore suspension to facilitate better fungus-insect contact. After about 4 weeks, half of the treated whitegrubs died due to mycosis. There was no visible growth of fungus in some dead grubs, especially where early mortality was recorded. This may be due to the reason that fungi secrete a wide array of compounds that exhibit biological activity against insects (Vey *et al.* 2001). *B. brongniartii* produces oosporein which affects enzymes functioning by redox reactions and is effective against cockchafer larvae (Vey *et al*. 2001). Growth pattern on insect body was characterized by formation of loose or tough mycelial mat with cushions or areas of conidial structures. The conidia were formed solitarily on a laterally proliferating conidiogenous cell often showing a geniculate or zig-zag type of elongation. However, after 5-6 weeks, most of the grubs were covered with white mat of mycelium. The globose shape and size (2.0-3.3x 2.0-2.5 µm) of conidia and shape and structure of conidiogenous cells resembled the description given by Samson (1981).

Establishing the pathogenicity of *B. bassiana* against whitegrubs

The pathogenicity of all four strains of *B. bassiana* isolated from Shillaroo, Kheradhar, Kharapathar and Solan was tested against second instar grubs of *B. coriacea* under laboratory conditions at Palampur. The dose of each strain was standardized to 401×10^4 conidia/ml. The grubs were given dip treatment in the conidial suspension for about 10 seconds. There was no mortality of grubs up to 7 days, however, after about 2 weeks, 20% of mortality of whitegrubs was recorded with Shillaroo strain of *B. bassiana*. After about 4 weeks, considerable mortality (77%) was recorded with all the strains. Prior to death, the whitegrubs stopped feeding, turned sluggish and the growth was arrested. After about 6 weeks, there was development of white mycelial growth on the body of grubs. When the fungal infested grubs were dissected, their haemocoel was completely filled with whitish fungal growth. Koch's postulates were proved to confirm the pathogenicity of the isolated fungus (*B. bassiana*).

Effect of temperature on growth and development of *B. bassiana*

Growth and sporulation of 4 isolates of *B. bassiana* collected from Shillaroo, Kheradhar, Kharapather and Solan was observed at 20 to 26 ^{o}C. There was gradual increase in radial growth of fungus with increase in temperature up to 26^{o}C as shown in Table 2. After 15 days of incubation, the diameter of Shillaroo isolate was recorded to be 7.66 cm.

B. bassiana strain obtained from Solan exhibited radial growth of less than 6.0 cm at 20 ^{o}C. However, at 26 ^{o}C, both Solan and Shillaroo isolates were statistically at par with each other. The Kharapather isolate showed growth at par with Solan isolate both at 20 and 22 ^{o}C. At 26 ^{o}C, the Kharapather and Solan isolates produced equal growth (7.60 cm) and were at par with Shillaroo isolate. There was lesser growth of Kheradhar isolate at all the temperatures as compared to all other isolates. The optimum temperature for growth and sporulation of *B. bassiana* has been reported to be ranging between 20-30 ^{o}C (Kuberappa and Jayaramaiah 1987). Sharma *et al.* (1998) demonstrated that temperature of 28 ^{o}C is most favourable for growth and sporulation of *B. bassiana* and *M. anisopliae*. They observed gradual increase in growth of *B. bassiana* with temperature. The results in the present study are totally in accordance with their findings. Among different isolates, Shillaroo isolate showed significantly higher multiplication in terms of mycelium development. This higher multiplication of Shillaroo isolate may be related to the virulence of the isolate and can cause early mortality in whitegrubs in high hills where average soil temperature fluctuates between 20 to 25 ^{o}C during cropping period.

Table 2. Effect of different temperatures on growth of *B. bassiana*

Strain	Radial growth (cm) of fungus after 15 days of incubation			
	20 ^{0}C	22 ^{0}C	26 ^{0}C	Mean
Shillaroo	6.19	6.90	7.66	6.92
Kharapather	5.80	6.10	7.60	6.50
Solan	5.93	6.19	7.60	6.57
Kheradhar	5.50	5.80	7.36	6.22
Mean	5.85	6.25	7.55	
LSD (P=0.05)	Strain	Temperature	Strain x Temperature	
	0.13	0.11	0.23	

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References

Arthurs S and Thomas MB 2001. Effects of temperature and relative humidity on sporulation of *Metarhizium anisopliae* var. *acridum* in mycosed cadavers of *Schistocerca gregaria*. *Journal of Invertebrate Pathology* **78**: 59-65.

Chandel RS, Chandla VK and Dhiman KR 2005. Vulnerability of potato whitegrub to entomogenous fungi and nematodes. *Potato Journal* **32** (3-4):193-194.

Chandel YS and Mehta PK 2005. Efficacy of some insecticides and entomopathogenic fungi for the management of whitegrub complex in potato. *Indian Journal of Ecology* 32: 195-199

Cisneros F and Vera A 2000. Mass- producing *Beauveria brongniartii* inoculum: An economical, farm level-method. CIP Program Report, pp 155-160.

Hajek AE and St. Leger RJ 1994. Interaction between fungal pathogens and insect hosts. *Annual Review of Entomology* **39**: 293-322.

Kuberappa GC and Jayaramaiah M 1987. Influence of temperature and humidity on the growth and development of the fungus, *Beauveria bassiana* (Bals.) A strain on the silkworm, *Bombyx mori* L. *Mysore Journal of Agriculture Sciences* **21**: 184-209.

Muller-Kogler E 1965. Pilzkrankheiten bei Insekten. Anwendung zur biologische Schadlingsbekampfung und Grundlagen der Insektenmykologie. Paul Parey, Berlin and Hamburg, pp 86-89.

Rai D, Updhyay V, Mehra P, Rana M and Pandey AK 2014. Potential of entomopathogenic fungi as biopesticides. *Indian Journal of Science Research and Technology* **2**:7-13.

Samson RA 1981. Identification: Entomopathogenic Deuteromycocetes. **In**: *Microbial Control of Pests and Plant Diseaeses,* ed Burges HD 1970-1980. New York, pp 93-106.

Sharma S, Gupta RBL and Yadava CPS 1998. Effect of temperature on growth, sporulation and bioactivity of entomofungi against whitegrub (*Holotrichia consanguinea*). *Indian Journal of Entomology* **60**:1-7.

Vey A, Hoagland RE and Butt TM 2001. Toxic metabolites of fungal biocontrol agents. **In**: *Fungi as biocontrol Agents: Progress and Potential,* eds Butt TM, Jackson CW and Magan N. CAB International UK, pp 311-346.

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Gross and morphometrical study on the external and internal nares of *Gaddi* sheep

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Abstract

An anatomical and morphometrical study was undertaken on the external and internal nares of 26 Gaddi sheep at Palampur during 2013-15. The results of the study revealed that the nostrils were slit like in Gaddi sheep and situated obliquely at rostral most part of head. The mean length of the nostrils was 2.51±0.52 cm. The mean distance between the dorsal commissures and ventral commissures was 3.26±0.54 cm and 1.04±0.25 cm, respectively. Nasal cavity of sheep extended from external nares to the chonae. The nasal cavity in Gaddi Sheep was provided with the three nasal turbinate bones (choanae) *viz*. dorsal, ventral and middle. Length of the dorsal turbinates ranged from 10.70 cm to 12.80 cm in adult animal. The width of the dorsal turbinate had range from1.90 to 2.70 cm with mean length of 2.36±0.40 cm. The length of the ventral nasal turbinate ranged from 9.90 to 12.20 cm, whereas its width was from 2.40 to 3.50 cm.

Key words: External nares, internal nares, morphometry

Sheep (*Ovis aries*) are quadrupedal ruminant mammals typically kept as livestock. Sheep are members of the order Artiodactyla, the double toed ungulates. The sheep is a multipurpose animal, which provides meat, milk, hide and wool for human consumption and manure for the use in improving soil fertility for crop production. Himachal Pradesh contributes around 1.26% of the countries sheep population (19th Livestock Census, 2012). In Himachal Pradesh especially in Kangra, Kullu, Shimla, Sirmour and Chamba, we find more concentration of sheep of Gaddi breed. Here it plays a vital role in saving the rural uneducated youths from unemployment. The importance of respiratory system increases due to continuous migration of animals from low hills to the high Alpine pastures and back, depending upon the different seasons of the year. The animals not only have to adjust their respiration to the different climatic zones but also have to deal with varying oxygen levels in the atmosphere. Although many studies have been conducted in the animals of plains but we still lack scientifically documented studies on Gaddi sheep. What so ever studies were conducted that were in bits and parts. Therefore, efforts were made to study the external and internal nares of Gaddi sheep.

Material and Methods

Present study was conducted on adult, healthy 26 *Gaddi* sheep from slaughter house. Heads were immediately collected after sacrifice. Sagittal and frontal sections of the head were made. The frontal sections were made at the level of 1st , 3rd , 4th palatel rugae, rostral margin of first cheek tooth; caudal to the third cheek tooth; caudal to the last cheek tooth; anterior to the rostral margin of orbits. With the help of hand lens and naked eye the external nares, nasal cavity and turbinate bones were examined to establish their anatomical relations. The morphometrical parameters were recorded with the help of digital Vernier's caliper. The data collected were subjected to statistical analysis.

Results and Discussion

External Nares

Nostrils lead to the nasal cavity. The nostrils were slit like (Plate-1) and situated obliquely at rostral most part of head. The aperture was comparatively longer in length than that of goat as also observed by Sinha *et al.* (2015) in goats. The nostrils were comma shaped in ox (Hare, 1975b), buffalo (Dhingra and Kumar, 1978) and dog (Hare, 1975b), semi lunar in horse (Hare 1975a) and circular in pig (Hare 1975c). The planum nasai situated between the nostrils was devoid of hair as also observed in Bangal Goat and Garole sheep by Sinha *et al.* (2015). Eshra and Badawy (2014) and Badawi and Fateh El-bab (1974) stated that camel and sheep had slit like nostrils with rostro-medially directed longitudinal axis. The nostrils were bounded by medial and lateral alae (wings). The wings met dorsally and ventrally to form commissure or angles (Plate-1). The mean length of the nostril was 2.51±2.12 cm (Table 1). The mean length of nostrils of yak was 4.50±0.05 cm, whereas mithun and zebu cattle nostrils measured 7.27±0.18 and 7.00±0.17 cm, respectively (Kalita and Kalita 2001). The mean width of the nostril of Gaddi sheep at center was 0.41±0.42 cm. The mean distance between the dorsal commissures and ventral commissures was 3.26±2.19 cm and 1.04±1.01 cm, respectively. Kalita and Kalita (2001) recorded the dorsal openings of zebu, Mithun and Yak as 1.20±0.12 cm, 1.20±0.12 cm and 8.80±0.06 cm and ventral openings as 2.60±0.16, 2.60±0.12 and 2.80±0.06 cm, respectively. There was no clear line of demarcation between external nares and internal mucosa.

Nasal Cavity

Nasal cavity of sheep extended from external nares to the chonae. These were conical shaped passages which were slightly bloated in the centre. Sharma *et al.* (1989) made similar observation on Gaddi sheep. The roof of the nasal cavity was formed by nasal bone and the inner table of the frontal bones. The nasal cavities were completely separated by the median nasal septum as observed in Gaddi sheep (Sharma *et al.* 1989), Gaddi goat (Gupta *et al.* 1992), buffalo (Dhingra and Kumar, 1978), yak (Sharma and Gupta, 1991), camel (Grossman 1960) and horse (Hare 1975a). However Hare (1975b) had reported that the nasal septum of ox remains separated from the nasal floor in its caudal thirds. In the dog, the division was also incomplete (Howard *et al.* 2013). The nasal septum of Gaddi sheep was mainly cartilaginous, vomer, ethmoid and palatine bones too contributed to its formation. Gupta *et al.* (1992) had observed that median nasal septum was mainly cartilaginous and small osseous part was formed by ethmoid and vomer bones in Gaddi Goat.

The nasal cavity in Gaddi Sheep had three nasal turbinate bones (choanae) *viz*. dorsal, ventral and middle. These turbinates increased the surface area many folds over which the air passed in the nasal cavity. The dorsal turbinate was the longest one. It extended from dorsal part of the ethmoid caudally to the level of first or second rugae palatine. Ganganaik *et al.* (2004) agree with the present study in sheep. Sharma *et al.* (1989) described that cranially dorsal turbinate extended up to the level of angularis oris in

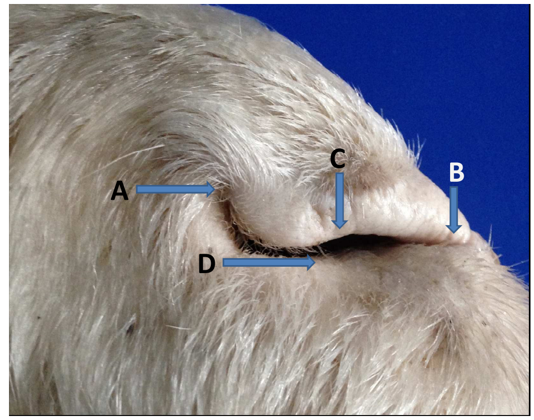

Plate 1. Nostril of Gaddi Sheep. Dorsal commissure (A), Ventral commissure (B), Dorsal lamina (C), Ventral Lamina (D)

Table1. Measurements of nostrils of Gaddi Sheep (N=16)

Parameter	Mean ±SE (mm)
Length (distance between dorsal commissure and ventral commissure)	25.15±0.52
Width	4.13±0.10
Distance A (distance between dorsal commissures)	32.60±0.54
Distance B (distance between ventral commissures)	10.47±0.25
Height (distance between line joining the dorsal commissures and ventral commissures)	15.60±0.13

gaddi sheep. Gupta *et al*. (1992) observed their cranial extension up to the rostral end of nasal bone in Gaddi goat. Hare (1975) limited its rostral extent up to the first cheek tooth in all the ruminants. Sharma and Gupta (1991) observed that the rostral limit of dorsal turbinate extended up to the nasal bones in Yak. It extended from the cribriform plate of ethmoid bone up to the 4^{th} transverse ruga of hard palate in case of goat (Singh *et al.* 1992). Length of the dorsal turbinates ranged from 10.70 cm to 12.80 cm in adult animal. The mean length of the dorsal turbinate in Gaddi sheep was recorded as 12.13±0.61 cm. The width of the dorsal turbinate ranged from1.90 to 2.70 cm. The mean length was recorded as 2.36±0.20 cm (Table 2). Dorsal concha in Gaddi sheep was almost non-sinuous at first and last cheek tooth levels, but had wide sinus at the level of 3^{rd} cheek tooth as reported by Sharma *et al.* (1989). However, Ganganaik *et al.* (2004) observed that the narrow cavity of dorsal sinus extended up to the level of medial canthus of eye in sheep.

Table 2. Gross parameters of the nasal turbinates of Gaddi sheep

Turbinate	Mean ± SE (cm)
Dorsal turbinate (L)	12.11±0.12
Dorsal turbinate (W)	2.36±0.04
Ventral turbinate (L)	11.33±0.09
Ventral turbinate (W)	3.18±0.04
Middle turbinate (L)	5.23±0.04
Middle turbinate (W)	2.62±0.02

N=23, P value >0.10, Length (L), width (W)

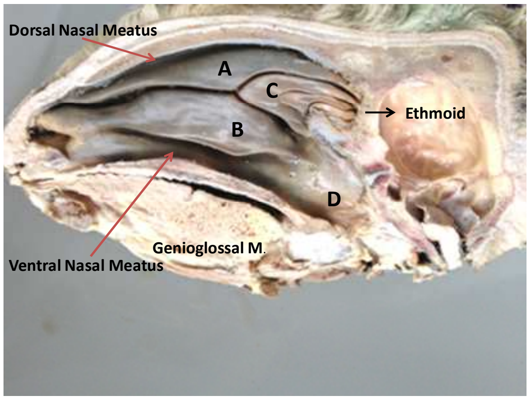

Plate 2. Sagittal section of the skull of Gaddi Sheep. Dorsal turbinate (A), Ventral turbinate (B), Middle turbinate (C), Nasopharynx (D)

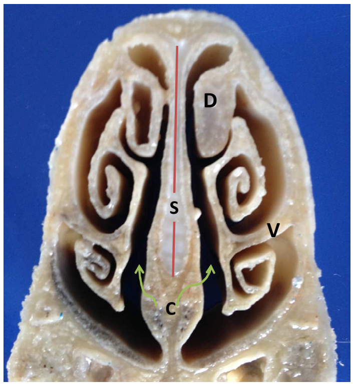

Plate 3. Transverse section of nasal cavity of Gaddi Sheep. Nasal septum (S), Dorsal nasal turbinate (D), Ventral nasal Turbinate (V), Common nasal meatus (C).

The ventral nasal turbinate was the largest one. It was fusiform in shape. It extended from the level of 4th cheek tooth to the tip of the nasal bone and ended into the alar fold. Ganganaik *et al.* (2004) observed their limit from third transverse ruga of hard palate to the level of caudal face of second molar tooth in sheep. May (1970) found it between the sphenopalatine foramen to the rostral end of nasal bone. Hare (1975) reported it between the last cheek tooth to the nasoincisive bone. While in buffaloes it was present at the level of third molar tooth (Dhingra and Kumar, 1978). The length of the ventral nasal turbinate ranged from 9.90 to 12.20 cm (mean 11.33±0.43 cm) (Table 2), whereas its width ranged from 2.40 to 3.50 cm (mean3.18±0.21 cm). Its width started decreasing with the appearance of middle concha, at the level of 3rd cheek tooth and diminished abruptly along the lateral and ventral wall of the ethomoturbinates ventral to the frontal sinus. The lamina divided into two, the dorsal and ventral scrolls (Plate 3). At the 1st cheek tooth level, the dorsal scroll had one complete turn, while the ventral had only half turn. At the third cheek tooth level, the dorsal scroll had 2 complete turns enclosing its double sinus whereas, the later had one complete turn enclosing one sinus. Ganganaik *et al.* (2004) reported that dorsal scroll had 1¼ turn and was devoid of conchal sinus whereas, the ventral scroll had 1½ turn and it enclosed a conchal sinus. Similar finding had been reported in goat (Singh *et al.* 1992). Gupta *et al.* (1992) found that the dorsal scroll had 2 turns and ventral scroll had 1½ turn in Gaddi goat.

The middle or the ethmoidal turbinate was pyramidal shaped structure having a shelf like arrangements (Plate 2). Its apex projected between the dorsal and ventral conchae at the level of 4th cheek tooth. The base lay along the cribriform plate of ethmoid bone, which corresponded to the last cheek tooth ventrally and supraorbital foramen dorsally. May (1970) observed that the rostral limit of the ethmoturbinate was at the 3rd cheek tooth level in sheep. Similar observations were made in Gaddi goat by Gupta *et al.* (1992). The length and width of the ethmoidal turbinate ranged from 4.90 to 5.60 cm (mean, 5.23±0.19 cm) and 2.30 to 2.80 cm (mean, 2.62±0.02 cm), respectively (Table-2). There were six ectoturbinates and five endoturbinates in Gaddi Sheep as also reported by Sharma *et al.* (1989). Gupta *et al.* (1992) reported 12 ectoturbinates and 4 endoturbinates in Gaddi goat. Singh *et al.* (1992) reported 5-6 ectoturbinates and 9-10 endoturbinates in goat. In a dog 6 ectoturbinates and 4 endoturbinates were present (Howard *et al.* 2013).

The choanae (posterior nares) were oval shaped, obliquely placed caudal openings of the nasopharyngeal meatus into the pharynx. They laid in the centre of the hard palate caudal to the last ruga at the level of 2nd cheek tooth. These openings were bounded ventrally by hard palate and dorsally by the fold of mucosa which extended from the ventral surface of vomer bone. They were separated from the oral cavity by means of the palatine bone and the soft plate. A median nasopharyngeal septum hung down from the roof of the nasopharynx from the 2nd cheek tooth to the level of pterigoid bone ventral to the sphenoid bone. Similar description had been given in pig (Hare, 1975c) and dog (Howard *et al.* 2013).

References

Nineteenth Livestock Census. 2012. Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries. Krishi Bhawan, New Delhi.

Badawi H and Fateh El-Bab MR. 1974. Anatomical and histological studies on the nasal cavity of the camel (*Camelus dromedaries*). Assiut Beterinary Medical Journal. 1:1-14.

Dhingra LD and Kumar S. 1978. Nasal cavity of Buffalo. Haryana agric. Univ. J. Res., Vol VIII (2), pp 107-119.

Eshra EA and Badawy AM. 2014. Peculiarities of the camel and sheep narial musculature in relation to the clinical value and mechanism of narial closure. Indian Journal of Veterinary Anatomy 26(1): 10-13.

Ganganaik S, Jain RK and Kumar P. 2004. Gross anatomy of the nasal cavity in sheep (*Ovis aries*). Indian Journal of Animal Sciences. 74(6): 605-608.

Grossman's the Anatomy of the Domestic Animals. philadelphia; W. B. Saunders Co. 5th ed. Vol.1.pp 768-69.

Gupta SK, Sharma DN and Bhardwaj RL. 1992. Anatomy of the nasal cavity of Gaddi goat. Indian Journal of Animal Sciences 62 (4): 294-296.

Hare WCD. 1975a. Equine Respiratory System in Getty's Sisson and Grossman's. *The Anatomy of the Domestic Animals.*, 5th (edn) Vol (1). W.B Saunders Co., Philadelphia, USA. pp. 458-61.

Hare WCD. 1975b. Ruminants respiratory system. In Getty's, Sisson and Grossman's The Anatomy of the Domestic Animals. 5th (edn), Vol 1, W B Saunders Company, Philadelphia, USA pp 916-19.

Hare WCD. 1975c. Porcine respiratory system. In Getty's, Sisson and Grossman's The Anatomy of the Domestic Animals. (5th edn) Vol 2 W B Saunders Company, Philadelphia, USA, pp 1283-85.

Hare WCD. 1995. The bronchopulmonary segments in the sheep. Journal of Anatomy 89: 387-402.

Howard E, Evans HE and Lahunta A. 2013. The Respiratory System. In Miller's Anatomy of the Dog. By Saunders imprint by Elsevier Inc. 4th (edn.) pp 338-360.

Kalita HC and Kalita PC. 2001. Morphometric study on the nostrils and muzzle in Mithun (*Bos frontalis*), Yak (*Bos grunniens*) and Zebu (*Bos indicus*). Indian Journal of Veterinary Anatomy 13 (2): 155-158.

May NDS. 1970. The Anatomy of Sheep. A dissection manual. 3rd edn. St. Lucia Queensland: University of Queensland Press.

Sharma DN, Gupta SK and Bhardwaj RL. 1989. Topographic anatomy of the nasal cavity of Gaddi Sheep. Indian Journal of Animal Research 23(2): 85-90.

Sharma DN and Gupta SK. 1991. Anatomy of the nasal cavity of yak (Bos grunniens). Indian Journal of Animal Sciences. 61(5): 478-481.

Singh I, Kumar S and Singh Y. 1992. Gross anatomy of the nasal conchae in goat. Indian Journal of Animal Sciences 62(12): 1160-1163.

Sinha MK, Ray S, Gautam AK, Singh MK and Ali L. 2015. Comparative Gross and Histological Studies on Nasal Cavity of Black Bangal Goat and Garole Sheep. Indian Journal of Veterinary Anatomy 27(1): 53-54.

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Short Note

Performance of rice (*Oryza sativa* L.) varieties under aerobic cultivation in mid hills of Himachal Pradesh

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Abstract

Aerobic rice is a method of rice cultivation in which the crop is raised under un–puddle non–saturated aerobic condition with high external inputs with the objective of achieving higher productivity and water use efficiency. A field experiment was conducted during *kharif* 2012 at Malan to standardize seeding time for six promising rice varieties (four high yielding varieties and two locally recommended hybrids) under aerobic conditions. Each variety was sown at three different dates (10, 20 and 30 June). On an average, significantly higher grain yield was recorded when the sowing was done on 20 June though it was at par with 10 June sowing. Among the varieties, on an average hybrid PAC 807 gave significantly highest yield followed by Arize 6129. However, while comparing different combinations of seeding and variety altogether, Arize 6129 gave significantly highest yield when sown on 10 June. Among the HYVs tested, highest yield was recorded from HPR 1068 while HPR 2143 gave lowest yield. The economic indices calculated also showed similar trend with hybrids showing higher values for gross and net return but had lower B:C ratio owing to the higher cost of seed.

Key words: Aerobic rice, date of sowing, variety

Rice (*Oryza sativa* L.) is the most important cereal crop of the country. It is cultivated on an area of 43.42 million hectare with an average productivity of 2279 kg ha^{-1} (Anonymous 2014a). It is a staple food for majority of the population of Himachal Pradesh where it is cultivated on an area of about 76.34 thousand hectare with productivity of 1736 kg/ha (Anonymous 2014b). Rice is mostly grown under submerged condition which results in very low water use efficiency besides ecological consequences such emission of green house gases. With the global water crisis looming large due to increasing alternate demands for water, it has become imperative to develop technologies that produce rice using lower quantities of water (Bouman 2001). Aerobic rice is water saving rice production system in which the crop is grown in non – puddled aerobic soils under irrigation and high external inputs (Bouman *et al* 2002). This system of rice cultivation saves water by eliminating wetland preparation (water required for puddling) necessary to avoid seepage and percolation and by reducing evaporation. In this system the crop is frequently irrigated to keep the moisture content between 70 and 100% of water holding capacity throughout the crop growing season. However, to make this technology viable, suitable package of practices need to be developed for various rice growing areas. Considering the above facts, the present investigation was carried out to find out optimum seeding time for different promising varieties of rice for realizing higher yields under aerobic condition.

A field experiment was conducted at the Experimental Farm of Rice and Wheat Research Centre, Malan during *kharif* 2012 to see the performance of different rice varieties grown at different dates of sowing under aerobic conditions. The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 5.7) with available nitrogen, phosphorus and potassium content of 322 kg/ha, 28.4 kg/ha and 236 kg/ha, respectively. Six varieties (four HYVs *viz.* HPR1156, HPR 1068, HPR 2143 and RP 2421 along with two locally recommended hybrids Arize 6129 and PAC 807) were sown at three different dates (10, 20 and 30 June). The experiment was laid out in split plot design with dates of sowing in main plot and varieties in sub plot with three replications. The seed was treated with carbendazim (2.5 g/ kg seed) and then soaked in water for 10 hours followed by incubation for 12 hours. Seeds were then dibbled in well leveled seedbed at a spacing of 20 cm x 10 cm using a seed rate of 40 kg/ha. Thinning/gap filling was done at 15 days after sowing (DAS) to obtain optimum plant population. To manage the weeds, pre–emergence application of butachlor (1.5 kg/ha) was done at 3 DAS followed by one hand weeding at 40 DAS. The crop was fertilized with recommended dose of fertilizers (90:40:40) with entire dose of phosphorus and potash along with 50% of recommended nitrogen at sowing. Remaining nitrogen was applied in two equal splits at active tillering and panicle initiation stages. Irrigation was applied immediately after sowing to hasten the germination and crop establishment. Subsequent irrigations were provided as and when required so as to maintain the field at near saturation without stagnation. Data were recorded on yield and yield attributes and subjected to analyses of variance with mean comparison at 5% level of significance. The economic indices were worked out based on the prevailing local market prices.

Significantly higher grain yield was recorded when the crop was sown on 20 June. Though, it was at par with the 10 June sowing date. Sowing on 30 June gave significantly lowest yield (Table 1). The results are in conformity with the findings of Naik *et al*. (2015) who also recorded highest yield when the aerobic rice was sown on 18 June with decline in yield with each successive date of sowing. The lowest yield recorded from the last date of sowing (30 June) was due to the lowest number of panicles/m^2. The reduction in number of productive tillers due to delayed sowing has also been reported by Dawadi and Chaudhary (2013). Amongst the varieties tested significantly highest grain yield was recorded from hybrid PAC 807 followed by hybrid Arize 6129. Amongst the different HYVs evaluated highest yield was obtained from HPR 1068. HPR 2143 gave significantly lower yield, though it was at par with RP 2421. The higher yield of hybrids was mainly due to higher panicle weight. Similar results showing the superiority of hybrids when grown under aerobic conditions have also been reported by Ningaraju *et al.* (2015). The interaction between the dates of sowing and varieties was significant for grain yield (Table 2). At the first date of sowing (10 June), hybrid Arize 6129 resulted in highest yield which was even significantly higher than the grain yield recorded

Table 1. Effect of varieties and date of sowing on the yield attributes, yield and economics of aerobic rice

Treatment	Panicles/m^2	Panicle weight (g)	Grain yield (t/ha)	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
Date of sowing							
10 June	322	1.85	3.93	26653	64540	37887	1.42
20 June	332	1.92	4.16	26653	68855	42202	1.58
30 June	277	1.82	3.33	26653	54315	27662	1.04
CD (P = 0.05)	15.32	NS	0.36	-	-	-	-
Variety							
HPR 1156	329	1.56	3.53	25080	59600	34610	1.38
HPR 1068	305	1.92	3.83	25080	61990	36910	1.47
HPR 2143	262	1.89	3.32	25080	53335	28255	1.13
RP 2421	346	1.54	3.53	25080	60140	35060	1.40
ARIZE 6129	299	2.11	4.19	29800	68945	39145	1.31
PAC 807	321	2.16	4.45	29800	71450	41650	1.40
LSD (P = 0.05)	17.36	0.18	0.23	-	-	-	-

Table 2. Interaction effect of date of sowing and variety on yield of aerobic rice

Variety	Date of sowing			
	10 June	20 June	30 June	Mean
HPR 1156	2.97	4.11	3.51	3.53
HPR 1068	4.04	4.16	3.28	3.83
HPR 2143	3.07	3.53	3.36	3.32
RP 2421	3.80	4.09	2.68	3.53
ARIZE 6129	5.36	4.48	2.73	4.19
PAC 807	4.36	4.58	4.42	4.45
Mean	3.93	4.16	3.33	
LSD (P = 0.05)				
Date at same or different variety				0.40
Variety at same date				0.44

from all other varieties tested. However, this variety showed a decline in yield with each subsequent date of sowing with significantly lowest yield recorded when the crop was sown on 30 June. This was probably due to the long duration nature of this variety with yields reduced due to exposure to low temperatures at the time of grain filling and maturity in later dates of sowing. Contrary to this hybrid PAC 807, which is a short duration hybrid, gave yields that were at par at all three dates of sowing with highest yield recorded from 20 June sowing. The HYVs also behaved in a similar manner with all the HYVs giving higher yields when sown on 20 June as compared to other two dates of sowing.

The economic indices calculated for various treatments have been given in Table 1. The gross return as well as net return followed the same trend as that of the grain yield with highest values recorded from hybrid PAC followed by Arize 6129. HPR 1068 gave highest values amongst the HYVs. However B:C ratio showed a different trend with highest value recorded from HPR 1068 (1.47) with hybrids showing lower values. This lower value in hybrids was due to the higher cost of seed which resulted in higher cost of cultivation for these varieties. Amongst the different dates of sowing, 20 June sowing gave highest gross return, net return and B:C ratio while lowest values for all these indices was recorded when the crop was sown on 30 June.

From the above study it can be concluded that in general 20 June is the best time for sowing of aerobic rice. Sowing later than this date should be avoided. Also both the recommended hybrids (PAC 807 and Arize 6129) gave higher yield under aerobic conditions while HPR 1068 proved to be better amongst the HYVs tested. If the farmers are to use hybrid Arize 6129, its sowing should not be delayed beyond 10 June.

References

Anonymous 2014a. Agricultural Statistics. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Anonymous 2014b. Statistical Year Book of Himachal Pradesh. Department of Economics and Statistics, Government of Himachal Pradesh, Shimla. pp 68-70.

Bouman BAM 2001. Water - efficient management strategies in rice production. Int. Rice Res. Notes 16: 17 – 22.

Bouman BAM, Wang HQ, Yang XG, Zhao JF and Wang CG 2002. Aerobic rice (Han Dao): A new way of growing rice in water-short areas. In: Proceedings of the 12th International Soil Conservation Organization Conference, Beijing, China 26–31 May 2002. pp 175 – 181.

Dawadi KP and Chaudhary NK 2013. Effect of sowing dates and varieties on yield and yield attributes of direct seeded rice in Chitwan, Nepal. Int. J. Agric. Sci. Res. 2(4): 95 – 102.

Ningaraju GK, Ramachandra N, Shivakumar M, Rajanna P and Krishnamurthy R 2015. Studies on response of varieties and different dates of sowing on productivity of aerobic rice. J. Rice Res. 3: 142.

Naik BB, Reddy DR, Sreenivas G and Rani PL 2015. Yield and water productivity of aerobic rice (*Oryza sativa* L.) as influenced by dates of sowing and varieties during *kharif* season. J. Rice Res. 8(1): 52 – 56.

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Short Note

Correlation and path analysis of agro-morphometric traits in maize (*Zea mays* L.)

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Abstract

Correlation and path coefficient among eleven agro-morphometric traits of forty maize inbred lines (14 QPM lines and 26 non-QPM lines) grown during *kharif* 2011 were studied. Correlation analysis revealed that grain yield exhibited significant positive association with 100-seed weight implying that improvement in grain yield can be obtained by improving the latter. Further, path coefficient analysis partitioned the correlation into direct and indirect effects. Path analysis revealed highest positive direct effect of days to 50% silking on grain yield, followed by cob girth and 100-seed weight; hence selection based on these characters would be more rewarding.

Key words: Maize, agro-morphometric traits, correlation, path analysis

Maize (*Zea mays* L.) belongs to the tribe Maydeae of the grass family Poaceae. The genus *Zea* consists of four species, of which *Z. mays* L. is economically important and is one of the nature's most efficient energy-storing cereal. It has the highest potential for carbohydrate production per unit area per day. It is a major food and calorie source for the people in the developing world, with a total direct consumption of 100 mt as food, contributing 15% of the protein and 19% of the calories delivered from food crops. The crop improvement efforts are directed to increase the grain production. Grain yield is a complex trait conditioned by the interaction of various growth and physiological processes throughout the life cycle. A rational choice of characters on which selection is to be exercised for higher yields requires an understanding of the association of characters with yield and among themselves. Further path coefficient analysis is an efficient tool to elucidate the direct and indirect effect of each character towards yield. Hence, the present investigation was taken up to study the association of yield and its component traits in maize.

The study was carried out at the Experimental Farm of the Department of Crop Improvement, College of Agriculture, CSK HPKV, Palampur (32°6' N latitude, 76°3' E longitude and 1290.8 m altitude) during 2011. The experimental material consisted of 40 maize inbred lines which comprised of 14 QPM lines and 26 non-QPM lines was sown in α-RBD design with three replications (five blocks per replication and eight entries per block with plot size of 3.0 × 1.2 m^2) at row to row and plant to plant distance of 60 cm and 20 cm, respectively (having 2 rows/plot). Recommended cultural practices were followed to raise the crop. Plant height, cob placement height, cob length, cob girth, kernel rows per ear, grains per row and 100-seed weight were recorded on ten randomly selected plants in each plot. Grain yield was harvested from net plot. Days to 50% pollen shed, 50% silking and 75% maturity were recorded on plot basis. The phenotypic [r_{12} (P)] and genotypic [r12 (G)] correlation coefficients were calculated as per formulae suggested by Al -Jibouri *et al.* (1958).

$$r_{12-}\,(P) = s_{p12}\,/\,\sqrt{[\,s^2_p\,(X_1) \times s^2_p\,(X_2)]}$$
$$r_{12-}\,(G) = s_{g12}/\,\sqrt{[s^2_g\,(X_1) \times s^2_g\,(X_2)\,]}$$

Where,

s_{p12} = phenotypic covariance between characters X_1 and X_2

s_{g12} = genotypic covariance between characters X_1 and X_2

$s^2_p(X_1)$ and $s^2_p(X_2)$ = phenotypic variance of traits X_1 and X_2, respectively

$s^2_g(X_1)$ and $s^2_g(X_2)$ = genotypic variance of traits X_1 and X_2, respectively

The path coefficient analysis was performed according to Dewey and Lu (1959).

$Py_1 + Py_2.r_{12} + Py_3.r_{13} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + Py_n.r_{1n} = ry_1$

$Py_1.r_{12} + Py_2 + Py_3.r_{23} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + Py_n.r_{2n} = ry_2$

$Py_1.r_{13} + Py_2.r_{23} + Py_3 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + Py_n.r_{3n} = ry_3$

$Py_1.r_{1n} + Py_2.r_{2n} + Py_3.r_{3n} \ldots\ldots\ldots\ldots\ldots\ldots + Py_n.r_{(n-1)n} = ry_n$

Where,

Py_1, Py_2, Py_3 ………….. Py_n are the direct path effects of 1, 2, 3, ………, n variables on the dependent variable 'y'.
r_{12}, r_{13},………….. r (n-1) n are the coefficients of correlation between various independent variables and ry_1, ry_2, ry_3, …………… ryn are the correlation coefficients of independent variables with dependent variable 'y'.

The variation in the dependent variable which remained undetermined was assumed to be due to variables (s) not included in the present investigation. The degree of determination of such variables was calculated as follows:

$$\text{Residual effect } (P \times R) = \sqrt{(1 - R^2)}$$

where,

$$R^2 = \sum_{i=1}^{n} p_{iy} r_{iy}$$

where,

R^2 is the squared multiple correlation coefficient and is the amount of variation in the yield that can be accounted for any yield component characters. Morphological traits were measured based on maize descriptors developed by the Biodiversity International.

The estimates of phenotypic and genotypic correlation coefficients among yield and yield attributes are presented in Table 1. The estimates of genotypic correlations, in general, were higher than their respective phenotypic correlations for most of the traits, indicating that the interrelationships were strongly inherent. The low phenotypic expression was due to environmental factors.

Days to 50% pollen shed exhibited a significant and positive association with 50% silking and 75% maturity. Similarly, significant positive correlation was also observed for 50% silking with 75% maturity indicating that selection for early silking would be sufficient to identify the earliness in maturity which would ultimately result in higher yield. Grain yield showed significant positive correlation with 100-seed weight indicating that this trait can be considered for effective selection. The grain yield was also positively correlated with all the other traits. Liu (1997) also reported positive correlation between grain yield and seed weight. Similar results were reported earlier in maize by Kaundal and Sharma (2005), Rafiq *et al.* (2010) and Zarei *et al.* (2012) which were in confirmation with the present study. Whereas, Barros *et al*. (2010) observed negative correlation between grain yield and days to silking, this was not in accordance with the present study, as these traits were positively correlated.

Path coefficient analysis (Table 2) provides better means for selection by resolving the correlation coefficient of yield and its components into direct and indirect effects. In the present study, six traits *viz.*, days to 50% silking, plant height, cob placement height, 100-seed weight, cob girth and grains per row exhibited positive correlation with grain yield. Whereas, days to 50% pollen shed, 75% maturity, cob length and kernel rows per ear exhibited negative correlation with grain yield. Geetha and Jayaraman (2000) reported that number of grains per row exerted a maximum direct effect on grain yield. However, in the present study the direct and indirect contribution of correlation revealed the high positive direct effect of days to 50% silking only, so this trait may be given more emphasis for selecting high yielding maize genotypes.

The high positive direct effect of days to 50% silking on yield was also reported by Kumar and Singh (2004) which were in confirmation with present study. From the present study it can be inferred that the traits showing positive direct effects on correlation with grain yield have low direct values, indicating that selection based on these traits for increasing the grain yield would not be effective. Whereas, their indirect effects through days to 50% silking were high, therefore 50% pollen shed, 75% maturity, cob placement height and 100-seed weight contributed indirectly through days to 50% silking which means that these traits act as precursors for other traits and selection on their basis would help in increasing the grain yield of maize.

References

Al-Jibouri HA, Miller PA and Robinson HF 1958. Genetic and environmental variances and covariances in upland cotton cross of interspecific origin. J. of American Society of Agro. **50**: 633-637.

Barros LB, Moreira RMP and Ferreira JM 2010. Phenotypic, additive genetic and environment correlations of maize landraces populations in family farm systems. Scientific Agric. **67** (6): 685-691.

Table 1. Estimates of correlation coefficients at phenotypic (P) and genotypic (G) levels among various yield and morphological traits of maize

Traits		Days to 50% silking	Days to 75% maturity	Plant height (cm)	Cob placement height (cm)	Grain yield (kg/ ha)	100-seed weight (g)	Cob length (cm)	Cob girth (cm)	Kernel rows/ ear	Grains/row
Days to 50% pollen shed	**P**	0.996*	0.990*	0.086	0.226	0.147	0.116	0.020	-0.063	-0.080	-0.191
	G	0.999	0.998	0.093	0.251	0.154	0.129	0.022	-0.066	-0.090	-0.212
Days to 50% silking	**P**		0.994*	0.104	0.231	0.175	0.136	0.029	-0.045	-0.081	-0.172
	G		1.000	0.109	0.259	0.181	0.154	0.041	-0.038	-0.085	-0.194
Days to 75% maturity	**P**			0.104	0.236	0.169	0.133	0.019	-0.047	-0.064	-0.178
	G			0.112	0.259	0.175	0.144	0.026	-0.042	-0.091	-0.207
Plant height (cm)	**P**				0.753	0.513	0.552	0.604	0.552	0.277	0.539
	G				0.790	0.556	0.603	0.717	0.637	0.349	0.611
Cob placement height (cm)	**P**					0.575	0.598	0.596	0.541	0.292	0.443
	G					0.621	0.659	0.680	0.611	0.344	0.478
Grain yield (kg/ ha)	**P**						0.695*	0.435	0.677	0.296	0.458
	G						0.751	0.538	0.842	0.398	0.579
100-seed weight (g)	**P**							0.540	0.731	0.350	0.499
	G							0.662	0.824	0.405	0.587
Cob length (cm)	**P**								0.650	0.377	0.682
	G								0.712	0.482	0.764
Cob girth (cm)	**P**									0.622	0.709
	G									0.761	0.743
Kernel rows/ear	**P**										0.351
	G										0.426

*Significant at 5% level of significance

Table 2. Estimates of direct and indirect phenotypic (P) and genotypic (G) effects of different traits on seed yield

Traits		Days to 50% pollen shed	Days to 50% silking	Days to 75% maturity	Plant height (cm)	Cob placement height (cm)	100-seed weight (g)	Cob length (cm)	Cob girth (cm)	Kernel rows/ ear	Grains/row
Days to 50% pollen shed	P	**-0.949**	-0.945	-0.939	-0.054	-0.179	-0.102	-0.024	0.064	0.084	0.194
	G	**-5.926**	-5.886	-5.786	-5.576	-1.023	-7.726	-1.302	3.948	5.379	12.739
Days to 50% silking	P	1.223	**1.229**	1.221	0.092	0.242	0.155	0.037	-0.064	-0.114	-0.233
	G	1.441	**1.442**	1.442	0.157	0.373	0.222	0.059	-0.055	-0.123	-0.280
Days to 75% maturity	P	-0.204	-0.205	**-0.206**	-0.015	-0.042	-0.025	-0.004	0.012	0.017	0.041
	G	7.980	8.116	**8.115**	6.486	1.069	8.391	1.524	-2.420	-5.294	-12.042
Plant height (cm)	P	0.002	0.002	0.002	**0.030**	0.023	0.017	0.017	0.017	0.008	0.016
	G	-0.085	-0.100	-0.102	**-0.916**	-0.724	-0.552	-0.657	-0.583	-0.320	-0.560
Cob placement height (cm)	P	0.031	0.033	0.034	0.124	**0.167**	0.096	0.090	0.088	0.047	0.072
	G	0.379	0.392	0.393	1.196	**1.514**	0.997	1.029	0.925	0.521	0.724
100-seed weight (g)	P	0.037	0.044	0.043	0.195	0.202	**0.350**	0.184	0.254	0.120	0.167
	G	0.888	1.060	0.995	4.153	4.540	**6.890**	4.564	5.680	2.793	4.044
Cob length (cm)	P	-0.004	-0.005	-0.003	-0.101	-0.096	-0.093	**-0.176**	-0.115	-0.070	-0.117
	G	-0.033	-0.062	-0.039	-1.081	-1.025	-0.999	**-1.508**	-1.073	-0.727	-1.152
Cob girth (cm)	P	-0.030	-0.023	-0.025	0.245	0.237	0.324	0.292	**0.446**	0.286	0.315
	G	1.037	0.598	0.655	-10.020	-9.619	-12.973	-11.200	**-15.737**	-11.979	-11.693
Kernel rows/ear	P	0.007	0.008	0.007	-0.023	-0.024	-0.029	-0.034	-0.054	**-0.084**	-0.031
	G	-0.682	-0.650	-0.692	2.651	2.616	3.080	3.664	5.784	**7.598**	3.236
Grains/row	P	-0.003	-0.003	-0.003	0.009	0.007	0.008	0.011	0.012	0.006	**0.016**
	G	-1.189	-1.087	-1.159	3.416	2.674	3.282	4.274	4.155	2.382	**5.592**

Residual effect (P) = 0.402, (G) = 1.762; Bold values indicate direct effects

Dewey DR and Lu KH 1959. A correlation and path analysis of components of crested wheat grass seed production. J. of American Society of Agro. **51**: 515-518.

Geetha K and Jayaraman N 2000. Path analysis in maize (*Zea mays* L.). Agric. Sci. Digest. **20** (1): 60-61.

Kaundal R and Sharma BK 2005. Genetic variability and association studies for different yield components over the environments in elite cultivars of (*Zea mays* L.). Him. J. Agric. Res. **31** (1): 26-31.

Kumar A and Singh NN 2004. Identification of yield contributors through path analysis in maize. Annals of Agric. Res. **25** (3): 448-450.

Liu Z 1997. Correlation analysis among kernel physical and quality characters in quality protein maize (QPM). Maize Genetics Cooperation Newsletter. **71**: 41.

Rafiq CM, Rafique M, Hussain A and Altaf A 2010. Studies on heritability, correlation and path analysis in maize (*Zea mays* L.). J. of Agric. Res. **48** (1): 35-38.

Zarei B, Kahrizi D, Aboughadaresh AP and Sadeghi F 2012. Correlation and path coefficient analysis for determining interrelationships among grain yield and related characters in corn hybrids. Inter. J. of Agric. and Crop Sci. **4** (20): 1519-1521.

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Short Note

Reactions of maize genotypes against banded leaf and sheath blight

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Abstract

Forty inbred lines of maize were indexed against banded leaf and sheath blight (BLSB) caused by *Rhizoctonia solani* f. sp. *sasakii*. The lines were artificially inoculated under pot culture conditions. Out of forty, four inbred lines *viz*., BAJIM08-90-1-6-1, BAJIM 6128, CML437-B-B, and CML 164 were found highly resistant (HR) with disease score of 1. Bajuara Makka 1, HKI 488, HKI 1105, CML 165, CML 336, CML 439, CML 437, BML 6, CML414, L 292, CML 437-B-B, L 265, BAJIM 95-60-5, CML 460, Sarhad-HSRB, LM 13, VQL 2, CML 169, and HKI 162 were rated as resistant with disease score of 3. The remaining inbred lines were highly susceptible.

Key words: Reaction, maize inbred lines/hybrids, BLSB, *Rhizoctonia solani* f. sp. *sasakii*

Maize (*Zea mays* L.) is an important cereal crop contributing towards world agricultural economy as food, feed and industrial products. Banded leaf and sheath blight (BLSB) of maize is caused by a destructive and versatile pathogen *Rhizoctonia solani* f. sp. *sasakii*. The disease causes huge crop losses in terms of grain and straw yield ranging from 11.0 to 40.0% (Singh and Sharma 1976). In India, this disease was first reported from Tarai region of Uttar Pradesh (Payak and Renfro 1966). Afterwards, Payak and Sharma (1981) reported the disease from Madhya Pradesh, Rajasthan, Haryana, Punjab and Himachal Pradesh. With the introduction of maize hybrids, the disease has become a major constraint for maize production in the state. Since the pathogen is soil borne, the disease starts from first leaf sheath to upward and even upto the ears to cause maximum damage. Warm-humid weather favours the development and spread of the disease. An op-timum temperature of about 28°C with relative hu-midity >88% favours rapid disease progress (Sharma 2005). The pathogen is characterized by formation of dull brown sclerotia on the host (Plate 1). Characteristic symptoms include concentric bands and rings on infected sheaths and leaves which are brown, tan or grey in color. The disease starts appearing on the first and second leaf sheath above the ground and eventually spreads to the ear causing ear rot. Ear rot is characterized by light brown, cottony mycelium on the ear and the presence of small, round, black sclerotia. The pure cultures of *Rhizoctonia solani* f. sp. *sasakii* are shown in Plate 2.

Evaluation of maize germplasm
Artificial inoculation

Forty maize inbred lines procured from Hill Agricultural Research and Extension Centre, Bajaura were evaluated against BLSB under pot culture conditions in the growth chamber of the Department of Plant Pathology, COA, CSK HPKV, Palampur with susceptible cultivar 'Kanchan' as a check. Five seeds of each entry were sown in a pot with three replications. Pots were marked with level of entries and kept in the green house. Twelve days old culture of *R. solani* f. sp. *sasakii* was mass multiplied in potato broth for inoculum production. Maize seedlings were artificially inoculated with cotton bits (dipped in inoculum of the casual fungus) on the axial of leaf sheath and blade. Pots were regularly sprinkled with water to maintain moisture. Watering of plants was done regularly twice a day in the morning and evening. The germinating seedlings of maize entry were covered with polythene bags having pores to maintain humidity >85%.

Plate 1: Dull brown sclerotia at basal sheath of inoculated maize seedlings

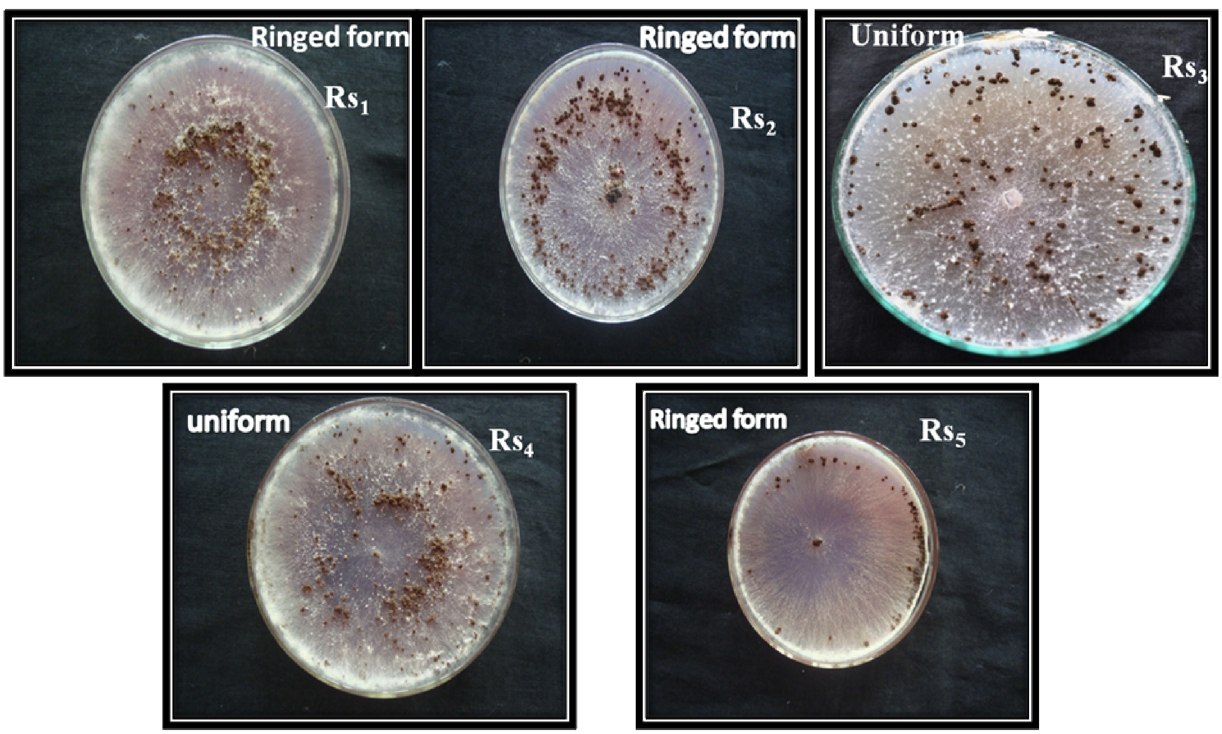

Plate 2. Cultures of *Rhizoctonia solani* f. sp. s*asakii*

After 20 days of inoculation, when seedlings collapsed completely in susceptible cultivar 'Kanchan', data were recorded for BLSB using 0-9 scale given by Wang and Dai (2001) to work out per cent disease index (PDI) as follows:

$$PDI = \frac{\text{Sum of all ratings of diseased seedlings}}{\text{Total number of observations x highest rating}} \times 100$$

Disease score	PDI	Symptom of disease	Reaction
0	0	No	I
1	0.1 – 20	Disease spots below 4th sheath under ear	HR
3	20.1 – 40	Disease spots below 3rd sheath under ear	R
5	40.1 – 60	Disease spots below 2nd sheath under ear	MR
7	60.1 – 80	Disease spots below 1st sheath under ear	S
9	80.1- 100	Disease spots over sheaths under ear	HS

I = Immune, HR = highly resistant, R = resistant, MR = moderately resistant, S = susceptible, HS = highly susceptible.

Reactions of maize inbred lines

Reactions of maize inbred lines against *Rhizoctonia solani*. f. sp. *sasakii* are presented in the Table 1. Four inbred lines *viz*., BAJIM08-90-1-6-1, BAJIM 6128, CML437-B-B, and CML 164 were found highly resistant with disease score of 1. The inbred lines *viz*. Bajuara Makka 1, HKI 488, HKI 1105, CML 165, CML 336, CML 439, CML 437, BML 6, CML414, L 292, CML 437-B-B, L 265, BAJIM 95-60-5, CML 460, Sarhad-HSRB, LM 13, VQL 2, CML 169, and HKI 162 were rated as resistant with disease score of 3.

Maize lines HKI 164-4 (1-3)-2, BAJIM 08-2, BAJIM 6130, B 57, L 290, CML 466, CML 460, LQPM 30, LQPM 34-1 and VQL 1 fell under the disease score of 5 and rated as moderately resistant. All others were susceptible (DMRQPM 60, Bajuara Makka, Girija and Early Composite) or highly susceptible (BAJIM-2780, BAJIM 8211 and BAJIM 3396). The results of disease score of genotypes/inbred lines were also shown in the Plate 3.

Kar (1998) reported inbred maize lines CM117 and CM211 as resistant to banded leaf and sheath blight caused by *R. solani* f. sp. *sasakii* and Bhavana and Gadag (2009) also reported inbred lines Pop 145 and Suwan-1 with high degree of tolerance to BLSB.

Plate 3. Reactions of maize lines to *R. solani* f. sp. *sasakii* under pot conditions

Table 1. Reactions of maize lines to *Rhizoctonia solani* f. sp. *sasakii* under pot conditions

Disease score	Genotype	Reaction
0	No	Immune (I)
1	BAJIM08-90-1-6-1, BAJIM 6128, CML437-B-B and CML 164	Highly Resistant (HR)
3	Bajuara Makka 1, HKI 488, HKI 1105, CML 165, CML 336, CML 439, CML 437, BML 6, CML414, L 292, CML 437-B-B, L 265, BAJIM 95-60-5, CML 460, Sarhad-HSRB, LM 13, VQL	Resistant (R)
5	HKI 164-4 (1-3)-2, BAJIM 08-2, BAJIM 6130, B 57, L 290, CML 466, CML 460, LQPM 30, LQPM 34-1 and VQL 1	Moderately Resistant (MR)
7	DMRQPM 60, Bajuara Makka, Girija and Early Composite	Susceotible (S)
9	BAJIM-2780, BAJIM 8211 and BAJIM 3396	Highly Susceptible (HS)

References

Bertus C 1927. A sclerotial disease of maize (*Zea mays* L.) due to *Rhizoctonia solani* Kuhn. Yearbook. Department of Agriculture Ceylon pp 47-48.

Bhavana P and Gadag RN 2009. Evaluation of maize genotypes for resistance to banded leaf and sheath blight. *Annals of Plant Protection Sciences* **17**: 498-499

Kar AK. 1998. Screening of maize inbred lines against maydis leaf blight and banded leaf and sheath blight diseases. *Plant Disease Research* 13: 56-57

Payak MM and Renfro BL 1966. Diseases of maize new to India. *Indian Phytopath. Soc. Bull.* **3**: 14-18.

Payak MM and Sharma RC 1981. Disease and pest situation in high yielding hybrids and composites of maize with special reference to India. A review of pest, diseases and weed complexes in high yielding varieties in Asia and Pacific. F.A.O. Regional office, Bangkok, Thailand. pp. 84-89.

Sharma RC 2005. Banded leaf and sheath blight (*Rhizoctonia solani* f. sp *sasakii*) of maize. In: Stresses of maize in Tropics. Zaidi, P. H. and Singh, N. N. eds. p.159- 171.

Singh BM and Sharma YR 1976. Evaluation of maize germplasm to banded sclerotial disease and assessment of yield loss. *Indian Phytopathology* **29**: 129-132.

Wang XM and Dai FC 2001. The field manual of plant diseases and insect pests of maize. Press of Agricultural Science and Technology of China.

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Short Note

Effect of post-emergence herbicides on productivity and profitability of garden pea (*Pisum sativum* L.) in Lahaul valley of Himachal Pradesh

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Abstract

A field experiment was conducted during summer 2013 at Highland Agricultural Research and Extension Centre, CSK Himachal Pradesh Krishi Vishvavidyalaya, Kukumseri to study the effect of post-emergence herbicides *viz*. imazethapyr 50 and 80 g/ha, pendimethalin + imazethapyr 900 and 1200 g/ha, imazethapyr + imazamox 50 and 75 g/ha and clodinafop 60 g/ha in relation to pre-emergence pendimethalin 1200 g/ha and hand weeding twice on weeds and yield and economics of garden pea. *Digitaria sanguinalis* L. was the predominant grass weed while *Chenopodium album* L., *Chenopodium botrys* L., *Gallinsoga parviflora* L. *and Malva parviflora* L. were the major broad-leaf weeds. Pendimethalin at 1200 g/ha significantly reduced weed density and dry weight. This was followed by hand weeding twice (30 and 60 DAS). Pendimethalin resulted in maximum weed control efficiency (65.81%) and herbicide efficiency index (74.13%) and was followed by clodinafop 60 g/ha. Pod weight was not significantly affected. The highest pods/plant, green pods yield (2833 kg/ha), crop productivity (41.06 kg/ha/day), net returns (₹ 76294/ha), crop profitability (₹ 1105.71/ha/day) and B:C ratio (3.06) were recorded under pendimethalin 1200 g/ha. Clodinafop 60 g/ha and hand weeding twice had equal pods/plant and green pod yield. Among post-emergence herbicides, clodinafop 60 g/ha, imazethepyr 50 g/ha and imazethapyr + imazamox 50 g/ha were the economical treatments.

Key words: Garden pea, weeds, imazethapyr, imazamox, clodinafop, pendimethalin, profitability, productivity

Lahaul representing cold desert area is an important vegetable growing region of the state. In Himachal Pradesh, the cold desert area constitutes about 42 percent of its total geographical area (Anonymous 2012). Garden pea (*Pisum sativum* L.) is an important off-season cash crop vegetable in the Lahaul valley. It is a major source of income for the Lahaul farmers as it fetches higher price due to its good aroma, sweetness and freshness. There is a great demand of garden pea in different parts of the country. Heavy weed infestation is one of the major reasons for poor productivity and profitability of garden pea in the region. The prevailing soil and climatic conditions warrant frequent irrigation for better growth and development of garden pea. Climatic conditions and frequent irrigation aggravate weed growth (Singh *et al.* 1991; Sharma 1993). Acute crop-weed competition occurs due to earlier weed germination and faster weed growth than garden pea particularly in initial growth stages. Lahaul farmers generally adopt manual weed control which is not only very expensive but also not feasible due to acute shortage of labour at the time of peak sowing and harvesting of the crop. Delayed harvesting of garden pea results in decreasing quality and green pod yield due to birds' attack.

Pre-and post-emergence herbicides are needed for effective weed control as there is acute weed infestation in the region. Post-emergence herbicides would be proved to be the best alternative in the case, when farmers could not apply pre-emergence herbicide in their crop due to its non-availability. For effective weed control in garden pea, there is no recommended post-emergence herbicide for the cold desert region of the state. Hence, the present investigation was undertaken to study the effect of post-emergence herbicides on weeds and yield and economics of garden pea.

A field experiment was conducted during summer 2013 at Kukumseri (32° 44' 55" N latitude, 76° 41' 23" E longitude, and 2672 m above the mean sea level). The climate is extremely cold and heavy snowfall occurs during winter. The temperature remains several degrees below zero level. Single cropping season is prevailing in the region which starts from April to September or early October when the mean minimum and maximum temperature range between 12°C to 24°C. There is negligible rainfall followed by high light intensity and low humidity. Average annual rainfall of the region is 250 mm. The soil of the experimental site was sandy loam in texture and acidic in reaction (6.1) with 10.5 g OC/kg soil, 0.9 mg Zn/kg soil, 18 kg S/ha, 280 kg available N/ha, 34 kg available P/ha and 300 kg available K/ha. Soils are shallow in depth and loose in texture resulting in poor water holding capacity. The experiment consisting of ten treatments *viz*. imazethapyr 50 & 80 g/ha, pendimethalin + imazethapyr (ready mix, valor) 900 and 1200 g/ha, imazethapyr + imazamox (ready mix, odyssey) 50 & 75 g/ha, clodinafop 60 g/ha, pendimethalin 1200 g/ha, hand weeding (30 & 60 DAS) and weedy check (Table 1) was laid out in randomized block design with three replications.

Garden pea cv Azad P-1 was sown on 22nd May, 2013 at 45 cm inter-row spacing with a seed rate of 100 kg/ha. Seed was treated with bavistin at 2.5 g/kg seed. Recommended dose of nutrients @ 25 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha was applied at the time of sowing through urea, single super phosphate and muriate of potash, respectively. Pendimethalin was applied next day of sowing whereas imazethapyr, odyssey, valor and clodinafop were applied at 30 days after sowing. Snow-melt water, the only source of irrigation was used to irrigate garden pea through sprinklers, rain gun or *Kuhl*. The crop was harvested on 30th July 2013. Other practices were in accordance with the recommended package for the region.

Weed density (stems/m^2 was noted due to dense and compact stems with rooting from nodes touched with soil), weed dry matter accumulation, yield attributes, green pod yield, productivity, cost of cultivation, gross returns, net returns, B:C ratio and profitability were recorded and/or computed after the harvest of the crop. Weed control efficiency (WCE) and herbicide efficiency index (HEI) were worked out using the following formulae:

$$HEI = \frac{\text{Yield in treated plot - Yield in control plot}}{\text{Yield in treated plot}} \times 100$$

$$WCE (\%) = \frac{\text{Weed dry weight in control plot - Weed dry weight in treated plot}}{\text{Weed dry weight in control plot}} \times 100$$

Statistical differences between treatments were tested with Fisher's least significant difference (P=0.05) test (Fisher and Yates 1949) using analysis of variance for randomized block design as described by Panse and Sukhatme (1967).

The experimental field was heavily infested with different weed flora. *Digitaria sanguinalis* L. was the predominant grass weed while *Chenopodium album* L., *Chenopodium botrys* L., *Gallinsoga parviflora L. and Malva parviflora* L. were the major broad-leaf weeds. Other weeds were *Polygonum alatum* L., *Setaria glauca* L., *Amaranthus spinosus* L., *Medicago denticulata* L. *and Poa annua* L. (Rana *et al*. 2004; Kumar *et al.* 2015a; Kumar *et al.* 2015b). *Digitaria sangunalis* L. was the most predominant weed.

Different weed control treatments significantly influenced weed density (Table 1). Pre-emergence application of pendimethalin 1200 g/ha significantly reduced the number of weeds. This was followed by hand weeding at 30 and 60 days after sowing and post-emergence application of clodinafop 60 g/ha. The weed dry weight showed the similar trend like weed density (Table 1). The lowest weed dry weight was recorded in pendimethalin 1200 g/ha followed by hand weeding at 30 and 60 days after sowing. Rest of the treatments produced similar dry matter. Pre-emergence application of pendimethalin 1200 g/ha had maximum weed control efficiency of 65.81% and herbicide efficiency index of 74.13%. Post-emergence application of clodinafop 60 g/ha was found to be the next best treatment in respect of weed control efficiency (40.17%) and herbicide efficiency index (58.88%). The highest weed density and weed dry matter accumulation was noted in weedy check. Pre-emergence application of pendimethalin suppresses weeds effectively resulting in low weed density and dry weight. Post-emergence herbicides were not as effective due to well establishment of weeds by 30 days after sowing resulted in acute crop weed competition.

The highest number of pods per plant was recorded with pre-emergence application of pendimethalin 1200 g/ha while the lowest was in weedy check (Table 2). The second highest number of pods/plant was recorded in hand

Table 1. Effect of herbicides on weed density and weed dry weight

Treatment	Dose (g/ha)	Time of application (DAS)	Grass weeds * (No./m^2)	Broad-leaf * weeds (No./m^2)	Weed dry weight (kg/ m^2)	Weed control efficiency (%)	Herbicide efficiency index (%)
Imazethapyr	50	30	55(3289)	4 (21)	1.10	5.98	45.01
Imazethapyr	80	30	54(2928)	2 (3)	1.09	6.84	39.22
Pendimethalin + imazethapyr**	900	30	48(2328)	2(3)	0.80	31.62	25.43
Pendimethalin + imazethapyr**	1200	30	53(2913)	1(1)	0.97	17.09	41.36
Imazethapyr + imazamox**	50	30	48(2335)	1(1)	0.73	37.61	39.72
Imazethapyr + imazamox**	75	30	49(2561)	2(5)	0.70	40.17	15.36
Clodinafop	60	30	34(1221)	6(49)	0.70	40.17	56.88
Pendimethalin	1200	2	21(672)	2(5)	0.40	65.81	74.13
Hand weeding	-	30 & 60	24(951)	1(1)	0.47	59.83	-
Weedy check (control)	-	-	57(3300)	4(20)	1.17	-	-
S Em±	-	-	4.28	1.24	0.17	-	-
C D (P=0.05)	-	-	12.71	3.67	0.52	-	-

*√x transformation ** ready mix

weeding followed by post-emergence clodinafop 60 g/ha and pendimethalin + imazethapyr 1200 g/ha. Green weight/ pod remained unaffected due to weed control treatments .

Green pod yield was significantly increased due to pre -emergence pendimethalin 1200 g/ha (2833 kg/ha). Hand weeding and post-emergence application of clodinafop 60 g/ha were the next superior treatments in influencing green pod yield (Table 2). Statistically equal pod yield was noted in manual weed control (two hand weeding at 30 and 60 DAS) and post-emergence application of clodinafop 60 g/ ha. Pendimethalin resulted in 286.49%, 40% and 37.84% higher green pod yield than weedy check, post-emergence application of clodinafop 60 g/ha and hand weeding, respectively. Post-emergence application of imazethapyr 50 g/ha showed superiority in respect of green pod yield over weedy check and imazethapyr + imazamox 75 g/ha. It gave 81.86 and 53.93% higher green pod yield than weedy check and imazethapyr + imazamox 75 g/ha, respectively. The highest crop productivity of 41.06 kg/ha/day was recorded with pre-emergence application of pendimethalin 1200 g/ha. Two hand weeding at 30 and 60 DAS and post-emergence application of clodinafop 60 g/ha were the next superior treatments (Table 2). Higher yield in these treatments might be due to less weed competition thereby more photosynthesis and better translocation of photosynthates (Dhanpal *et al*. 1989; Kundra *et al*. 1993; Rao *et al.* 1997; Rana, 2004; *Rana et al.*2013*;* Mawalia *et al.* 2015).

Since adoption of any technology depend on its economics, it is pertinent to have economic analysis of the treatments. The highest gross returns (₹ 1,13,320/ha), net returns (₹ 76,294/ha), B:C ratio (3.06) and profitability (₹ 1105.11/ha/day) was recorded with pre-emergence pendimethalin 1200 g/ha. This might be due to the highest green pod yield and low cost of its treatment. The highest cost of cultivation (₹ 63155/ha) was recorded in hand weeding. Post-emergence application of clodinafop 60 g/ha and imazethepyr 50 g/ha were the other economical treatments in garden pea. Hand weeding was not economical due to the higher cost of labour.

The present study inferred that clodinafop 60 g/ha as post-emergence is as good as pendimethalin 1200 g/ha as pre-emergence for the control of weeds and increasing productivity and profitability of garden pea in cold desert region of Lahaul valley.

Table 2. Effect of herbicides on yield attributes, yield and economics of garden pea

Treatment	Dose (g/ ha)	Time of application (DAS)	Pods/ plant	Pod weight (g/pod)	Green pod yield (kg/ha)	Crop productivity (kg/ha/day)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	Crop profitability (₹/ha/day)
Imazethapyr	50	30	1.63	3.83	1333	19.32	36115	53320	17205	1.48	249.35
Imazethapyr	80	30	1.45	2.96	1206	17.49	36535	48240	11705	1.32	169.64
Pendimethalin +imazethapyr**	900	30	1.36	3.36	983	14.25	37384	39320	1936	1.05	28.06
Pendimethalin +imazethapyr**	1200	30	1.77	3.16	1250	18.12	38040	50000	11960	1.31	173.37
Imazethapyr + imazamox**	50	30	1.63	3.23	1216	17.63	36344	48640	12296	1.34	178.20
Imazethapyr + imazamox**	75	30	1.36	3.03	866	12.56	36808	34640	-2168	0.94	-31.42
Clodinafop	60	30	1.90	4.10	1700	24.64	36465	68000	31535	1.86	457.03
Pendimethalin	1200	2	2.55	4.76	2833	41.06	37026	113320	76294	3.06	1105.71
Hand weeding	-	30 & 60	2.00	3.83	1761	25.52	63115	70440	7285	1.12	105.58
Weedy check (control)	-	-	0.81	3.33	733	10.63	34655	29320	-5335	0.85	-77.32
S Em±		-	0.69	0.37	143	-	-	-	-	-	-
LSD (P=0.05)		-	0.26	NS	424	-	-	-	-	-	-

** ready mix

References

Anonymous 2012. Status Report on Cold Arid areas of Himachal Pradesh. Directorate of Research, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, pp 54.

Dhanpal GN, Reddy BMV and Bommegowda A 1989. Screening of herbicide for dry land crops under Bangalore condition. *Mysore Journal of Agricultural Sciences* **23** (2): 159-163.

Fisher RA and Yates F 1949. *Statistical tables for Biological, Agricultural and Medical Research*. Oliver and Boys, Edinburgh. Pp 112.

Kumar A, Manuja S, Singh J and Chaudhary DR 2015a. Integrated weed management in tomato under dry temperate climate of western Himalayas. *Journal of Crop and Weed* **11(**1**)**:165-167.

Kumar A, Manuja S, Singh J and Chaudhary DR 2015b. Integrated weed management in cauliflower (*Brassica oleracea* var. botrytis) under dry temperate climate of western Himalayas. *Journal of Crop and Weed* **11**(2):168-171.

Kundra, HC, Singh, G and Brar, LS 1993. Efficacy of weed management practices in pea (*Pisum sativum* L.). *Indian Journal of Weed Science* **25**(1):1-6.

Mawalia AK, Kumar S and Rana SS 2015. Economics of post-emergence weed control in garden pea (*Pisum sativum* L.) under mid hill condition of Himachal Pradesh. *Himachal Journal of Agricultural Research* **41**(1): 15-29.

Panse VG and Sukhatme PV 1967. *Statistical Methods for Agricultural Workers,* Indian Council of Agricultural. Research, New Delhi, India, pp 381.

Rana M C, Kumar N, Sharma, A and Rana SS 2004. Management of complex weed flora in peas with herbicide mixtures under Lahaul valley conditions of Himachal Pradesh. *Indian Journal of Weed Science*. **36** (1&2): 68-72.

Rana MC, Nag M, Rana SS and Sharma GD 2013. Influence of post-emergence herbicides on weeds and productivity of garden pea (*Pisum sativum* L.)) under mid hill condition of Himachal Pradesh. *Indian Journal of Agronomy* **58** (2): 226-230.

Rao AR, Sharma SN and Mohammad S 1997. Impact of varying plant population and herbicide use on weeds, crop yield and profitability of rajmash. *Crop Research Hisar* **13**(2): 293-300.

Sharma, JJ 1993. Evaluation of herbicides in peas in midhills of Himachal Pradesh. *Indian Journal of Weed Science* **25** (3&4): 36-39.

Singh JS, Bhan VM and Balyan RS 1991. Crop-weed competition studies in pea *(Pisum sativum* L.*). Indian Journal of Weed Science* **23** (1&2): 67-68.

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Short Note

Evaluation of 'KL241': a new genotype of linseed (*Linum usitatissimum* L.) under *utera* cultivation

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Abstract

A field experiment was conducted during *rabi* 2014-15 at Palampur to evaluate a new genotype of linseed *viz. 'KL-241'* in comparison to *'Baner'* and *'T-397'*. The new entry *'KL-241'* was significantly superior to national check *'T-397'* in term of almost all growth and yield attributes *viz.* plant stand, number of capsules/plant and 1000-seed weight. However, number of primary and secondary branches and seeds/capsule were not significantly influenced due to genotypes. *'Baner'* (Zonal Check) was at par with '*KL-241*' for plant stand, number of capsules/plant and seed yield of linseed. *'KL-241'* registered 137.9 and 10.2% higher seed yield over *'T-397'* and *'Baner'*, respectively. Maximum net returns and B:C ratio of INR 10383/ha and 1.18, respectively, were obtained under *'KL-241'*, which was followed by zonal check-*'Baner'*.

Key words: Linseed, *Utera*, Varieties, Yield, Economics

Linseed (*Linum usitatissimum* (L.) Griesb.) is becoming increasingly popular as a nutritional and functional food. Seed is a rich source of both non-edible and edible oil. The oil crushed from the seeds can be used for either industrial or edible purpose, depending on the fatty acid composition (Burton 2007). Edible linseed oil is used for human consumption and contains high α-linolenic acid (ω 3 fatty acid), a polyunsaturated fatty acid along with high content of health promoting substances such as soluble and insoluble fibre and lignans (Genser and Morris 2003 ; Morris 2005). In Himachal Pradesh, released linseed cultivars have low linoleic and high linolenic acid composition which make them suitable for cooking purpose. In the state, linseed is generally broadcasted in standing paddy crop, 15 -20 days before its harvest. This relay system of cultivation is popularly known as '*utera*' or '*paira*'. The cultivation of linseed in this system is under total "Nature's care and cure" which results in lower productivity. The use of local land races susceptible to rust, other diseases and easily smothered by the weeds further limits linseed production in this system. The past efforts were limited to verification of genotypes and agrotechniques under prepared seed bed conditions and not for *utera* cultivation. Genotypes differ from each others in genetic make up for growth and yield and behave differently in different environments. Under *utera* system, varieties having small seed size and deep root system will be of much importance (Agarwal *et al.* 1986). A new entry *i.e. 'KL-241'*, (Giza-7 and KLS-1) having similar characters and performance needs to be confirmed under this system of cultivation.

Keeping this in view, the present study was conducted at Main Farm of Department of Crop Improvement, CSKHPKV, Palampur during *rabi* 2014-15 to evaluate the performance of new entry (*'KL-241'*) in comparison to two checks *viz. 'T-397'* (NC) and *'Baner'* (ZC) in randomized block design with seven replications under *Utera* system of cultivation. The soil of the experiment site was silty clay loam in texture with pH 5.9 and medium in available nitrogen, phosphorus and potassium. The crop was supplied with 60 kg N/ha. The crop was sown by broadcasting seeds of linseed at dough stage of paddy using seed rate of 75 kg/ha. The total number of plants present in 0.25 m^2 area were counted in a quadrate of 0.5 m x 0.5 m at random in each plot and expressed in number of thousand plants/ha. Plant height, number of primary and secondary branches and capsules/plant were recorded from the selected five plants in each net plot. The crop was harvested from net plot. It was sun dried and threshed with wooden mallet. The seed yield was expressed in kg/ha. Economics was calculated on the basis of prevalent market prices of inputs and outputs.

Among different genotypes, Zonal Check-*'Baner'* resulted in significantly more plant height followed by test entry *'KL-241'*. Test entry *'KL-241'* was statistically similar to zonal check-*'Baner'* for plant stand and number of capsules per plant. However, the test entry was significantly superior for 1000-seed weight. Different genotypes failed to influence the number of primary and secondary branches/plant and number of seeds/capsule. Owing to higher plant population and yield attributes, *'KL-241'* and *'Baner'* resulted in significantly higher seed, straw and biological yield. Although, both the entries behaved statistically similar to each other but yield advantage of about 10.24% was recorded under test entry *'KL-241'* over zonal check-*'Baner'*. There was an increase of 137.9 and 115.8% in the seed yield with *'KL-241'* and *'Baner'* over *'T-397'*. This might be due to better root development by these genotypes which helped in better absorption of nutrient and water in this system. Based on the best performance of *'Baner'* in *utera* system, this variety was released for Zone-I of India (Anonymous 2006). Similarly, *''KL-241''* was found to be highest yielding in both breeding and agronomic evaluation trials under similar conditions (Anonymous 2014 & 2015). The National Check *'T-397'* was found to be significantly inferior in all these aspects (Table 1).

Maximum gross, net return and B:C ratio of INR 19218, 10383/ha and 1.18, respectively were obtained under test entry *'KL-241'*, which was followed by Zonal check-*'Baner'*. *'KL-241'* registered an increase of INR 1786/ha in net return over the best check *i.e.* *'Baner'*. Higher production and almost similar cost of cultivation for raising *'KL-241'* as compared to *'Baner'* resulted in better returns. National Check, *'T-397'* was not at all acceptable from production and economic point of view (Table 1).

Table 1. Effect of genotypes on plant stand, plant height, yield attributes, yield and economics of linseed

Genotype	Plant stand (000'/ha)	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Capsules/ plant	Seeds/ capsule	1000-seed wt. (g)	Seed yield (kg/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
'KL-241'	2193.86	43.82	4.65	3.00	19.20	6.89	6.03	640.59	19218	10383	1.18
'T-397' (NC)	1083.57	35.05	3.97	2.80	15.80	6.26	4.54	269.28	8078	-172	-0.02
'Baner' (ZC)	1955.86	49.59	4.26	2.91	17.80	6.77	5.87	581.07	17432	8597	0.97
CD (P=0.05)	275.42	3.81	NS	NS	1.90	NS	0.11	60.77	-	-	-

References

Agarwal SK, Shrivastava PS and Singh R 1986. Package of practices for *utera* cultivation. Indian Farming **36**: 5-10.

Anonymous 2006. Annual Report, All India Coordinated Research Project on Linseed, Project Coordinating Unit, CSAUA&T, Kanpur, 2005-06, pp ii.

Anonymous 2014. Annual Report, All India Coordinated Research Project on Linseed, Project Coordinating Unit, CSAUA&T, Kanpur, 2013-14, pp 54.

Anonymous 2015. Annual Report, All India Coordinated Research Project on Linseed, Project Coordinating Unit, CSAUA & T, Kanpur, 2014-15, pp 47.

Burton A 2007. Field plot conditions for the expression and selection of straw fiber concentration in oilseed flax. Ph. D. Thesis, University of Saskatchewan Saskatoon, Saskatchewan, Canada.

Genser AD and Morris ND 2003. History of cultivation and uses of flaxseed. In: *Flax -The genus Linum*, eds Muir AD and Westcott ND. Taylor and Francis. London.

Morris DH 2005. Flax-A health and nutrition primer. (F. C. O. Canada, ed.). Flax Council of Canada. http://www.flaxcouncil.ca/primer.htm

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Short Note

Preliminary studies on semi-hardwood grafting technique in apple under polyhouse condition in mid hill area of Himachal Pradesh

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Abstract

A study was carried during 2012-13 at Palampur to investigate the possibilities of semi-hardwood grafting technique in apple under polyhouse. The tongue grafting was performed on four different dates (September 11, 18, 25 and 29, 2012). A success rate of 93.33 to 100% with proper callusing and healing of graft unions was achieved. Among different grafting dates, the plants grafted on September 11 attained the maximum height (25.10 cm) with lateral branching of 2.67 laterals/plant. The minimum plant height of 14.50 cm was recorded in plants grafted on September, 29. Similarly, total number of leaves, dry and fresh weight and chlorophyll content were also more in plants grafted on September 11. This technique needs to be investigated in apple and other temperate fruit plants under polyhouse condition for quick multiplication and reducing nursery production duration.

Key words: Semi-hardwood, grafting, apple, polyhouse, chlorophyll, callus, plant height, leaf weight

Plant propagation including grafting played an important role in mankind since the beginning of civilization when man started to grow crops (Mahunu *et al.* 2012). The grafting is a technique used to combine one plant part with another to encourage growth as a unified plant. It is accomplished by inserting a piece of stem containing 3 to 4 vegetative buds onto the stem of the plant that will serve as the root system for the unified plant (Hartmann *et al.* 2002). It has been successful in producing fruit trees of small and manageable sizes which are precocious, productive and true-to-type. The basis of unity between two parts of plants depends on mutual responsibility. Apart from tree or plant size control, grafting produces planting stock that has suitable characteristics such as resistance to pest and diseases. Additionally, it provides an opportunity to clonally propagate selected trees with desirable phenotypes (Kumar *et al*. 2015; Rana *et al*. 2015). The branch top-work grafting has been used to improve upon pollination in apple orchards having inadequate pollinizers (Sharma and Rana, 2015). The impact of grafting on apical dominance (Mapelli and Kinet 1992), mineral nutrition (Jayawickrama *et al.* 1992), flowering (Corbesier *et al*. 2007), dwarfism (White *et al.* 1992) and abiotic stress (Kumar *et al*. 2015) has been studied.

Almost all temperate fruit plants are multiplied through grafting, budding and tissue culture. Grafting is performed during dormant season whereas, budding in active growing season (June-September). However, there is no scientific research devoted to success of semi-hardwood grafting in apple to date except the shoot tip grafting of some woody plants including apple by grafting a small shoot tip of 0.1 to 1.0 mm, onto a young seedling rootstock growing *in-vitro*. The same technique has been used with citrus, peach, cherry, plum, apricot, apple, almond, grapevine, avocado, camellia and sequoia (Navarro 1988).

It takes complete two years to produce plants if grafted onto seedling rootstocks. Therefore, there is a need to invent new techniques to reduce this time. Although, *in-vitro* multiplication gives quick and disease free planting materials but it requires modernize and professionally qualified and competent manpower. Further, to meet the ever-growing demand and inadequate supply of quality planting materials, the semi-hardwood grafting technique could be employed under polyhouse condition for quick supply of plants. Moreover, the growth in polyhouse condition is faster and remains more as compared to open field condition. Therefore, the present experiment was conducted to determine the possibilities of semi-hardwood grafting in apple under polyhouse condition.

A semi-hardwood grafting experiment was conducted in apple cultivar Scarlet Gala as scion and M-7 clonal rootstock at Palampur, (32.1167 ^{0}N latitude, 76.533 ^{0}E longitude and 1280 m altitude) during 2012-13. Both the components (scion and rootstock) were multiplied *in-vitro* at The Energy and Resources Institute (TERI), New Delhi and hardened plantlets at three leaves stage were transferred to Palampur in April, 2011. After acclimatization and attainment of graftable size (17 month old), in polyhouse tongue grafting was done on September 11, 18, 25 and 29, 2012. On each grafting dates 21 plants were grafted and the scionwood having the same thickness of rootstocks was selected. While preparing scionwood, the middle portion (semi-hardwood) of shoots with at least three nodes was selected and leaves were removed with the help of secateur just leaving the petioles as such on them. Care was taken that all buds at each node were well developed and the wood was not succulent. The scionwood was detached directly from mother plant and no curing/preconditioning was done prior to the grafting, as done in most of the evergreen plants. The average temperature within the polyhouse was 27 ^{0}C during day time. No misting was done except cooling the structure by exhaust fans mounted in it. The observations were recorded from 15 representative plants selected randomly from each grafting date. The experiment was laid out in Randomized Block Design (RBD) with three replications. The growth of grafted plants was recorded at weekly interval starting from October 11 to December 5, 2012. In the following year, the plants were kept as such in beds and observations on various growth parameters and foliar characteristics were taken (data not presented).

Estimation of chlorophyll content

Dimethyl sulfoxide (DMSO) solvent was used to extract the chlorophyll from leaves as described by Hiscox and Israelstam (1979). Chlorophyll a (mg/cm^2), chlorophyll b (mg/cm^2) and total chlorophyll content (mg/cm^2) were calculated from absorbance at 663nm and 645 nm in UV Spectronic-20 according to Arnon's (1949) equations:

Chlorophyll a= (ml of solvent) [(0.0127 x absorbance 663)-(0.00269 x absorbance 645)]/leaf area (cm^2)

Chlorophyll b= (ml of solvent) [(0.0229 x absorbance 645) -(0.00468 x absorbance 663)]/leaf area (cm^2)

Total chlorophyll content = (ml of solvent) [(0.0202 x absorbance 645) + (0.00802 x absorbance 663)]/ leaf area (cm^2)

The wound healing process *viz*., callus formation, cambial differentiation and connectivity and vascular tissue formation was observed visually in both years (2012-13) without histological studies. The data were analyzed by using Assex, an MS-DOS based program and CPCS1 software at 0.05 % rejection level.

Bud take

The buds started bursting after 7 to 10 days of grafting. There was 93.33 to 100 % success with proper callusing and healing of graft wounds under different treatments (Table 1). The callus formation and wound healing were observed visually. It was observed that after 40 to 60 days of grafting, wounds were healed except those plants which were grafted on September 29, where the wound healing was a bit slow (data not presented).

The ontogeny of graft union formation was also observed in the following year (2013). There was no sign of abnormality and incompatibility in graft unions in any of the treatments. Although, it takes several years to check the incompatibility but in this study the growth of all the grafted plants was normal and no abnormality/overgrowth or necrotic portion in graft unions was observed as usually seen in incompatible combinations. Many workers in their histological studies have also confirmed the cambial connectivity in 45 days after grafting in fruit trees. In this study, the maximum growth of 5.60 cm after 30 days of grafting was recorded (Figure 1) in plants grafted on September 11.

It has been earlier reported that it took 30 days after grafting for proper cambial connectivity and vesicular formation in nectarine/almond combination (Tekintas and Doigun 1996) and 45 days after grafting for cambial connectivity in citrus (Tekintas 1991). Similarly, Polat and Kaska (1992) observed 40 days in pear/Quince-C combination. Oguz *et al.* (2008) reported that the establishment of cambial connectivity is vital for producing vesicular tissues. After this continuity, new cambium cells start to produce new vascular tissues which are the last stage of successful grafting. A good established vascular connection provides a good water and nutrient flow from rootstock to bud (Unal 1992).

Vegetative growth

The observation on plant growth during the year of grafting i.e. in 2012 was recorded at different intervals (Table 1 and Figure 1). Among different grafting dates the maximum growth (25.10 cm) was observed in plants grafted on September, 11 (T_1) while minimum in plants grafted on 29 September, 2012. During the course of investigation it was observed that the growth rate of all grafted

Table 1. Effect of grafting dates on bud take and vegetative growth in apple

Grafting date (2012)	Bud take (%)	Plant height (cm)	Laterals/plant (No.)	Radial growth (mm)	
				Above graft union	Below graft union
September, 11	100	25.53	2.67	12.68	14.21
September, 18	100	20.58	2.33	12.38	14.15
September, 25	100	18.91	1.67	11.60	13.13
September, 29	93.33	14.50	1.33	12.21	13.98
SEm±	--	0.35	0.49	0.28	0.41
$CD_{0.05}$	--	0.86	1.20	0.69	1.01

plants was highest at D_2 to D_5 interval (Figure 1) and the growth continued up to D_7 interval in plants grafted on September 11, 18 and 25. Whereas, the plants grafted on September, 29 ceased their growth much earlier i.e. from November, 16 (D_6) onwards. The overall average height was highest in plants grafted earliest (September 11) and it decreased linearly with the advancement of grafting dates (Table 1). Similarly, the number of lateral shoots per plant was also significantly affected by grafting dates (Table 1). It is clear from the table that maximum number of lateral shoots (2.67 shoots/plant) were recorded in plants grafted on September 11, however; it was statistically at par with plants grafted on September 18 and 25.

The radial growth of grafted plants both above and below graft union was also significantly influenced by grafting dates (Table 1). Although, no abnormal growth at graft union was observed in all plants but the radial growth was more in case of plants grafted on September 11. This was also an indication of healthy graft union formation as suggested by Simon and Elsa (2007), in histological evaluation of early graft compatibility in *Uapaca kirkiana* Muell Arg. scion/stock combinations. However, they had reported that the excess growth at graft union was first visual indicator of incompatibility between stock and scion.

Leaf characteristics

The foliar status of plants is also an indicator of plant health, and in this study also; these parameters were found significantly influenced by grafting dates (Table 2). Number of leaves per plant, dry and fresh weight and chlorophyll contents were found significantly affected by grafting

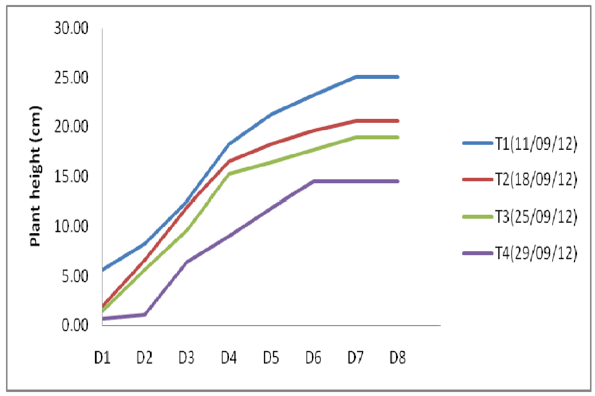

Fig 1. Growth pattern of apple plants grafted on different dates

dates and plants with healthy growth had maximum values of these parameters. The maximum fresh and dry weight of leaves was found in plants grafted in September 11; similarly, the total chlorophyll content in terms of mg/cm^2 leaf area was also more in these plants (Table 2). The foliar characteristics such as; leaf area, dry and fresh weight and chlorophyll contents are major parameters in determining the plant health and other physiological processes such as photosynthesis.

Thus from this study it can be concluded that semi-hardwood grafting in apple under polyhouse condition can reduce the duration of nursery production time. Further, this technique needs to be standardized for quick multiplication of other temperate fruit plants.

Table 2. Effect of grafting dates on leaf characteristics in apple

Grafting dates	No. of leaves/ plant	Leaf area (cm^2)	Leaf weight (g)		Chlorophyll content (mg/cm^2 leaf area)		
			Fresh	Dry	Chlorophyll a	Chlorophyll b	Total chlorophyll
September, 11	13.26	34.19	7.11	4.03	0.0223	0.0347	0.0589
September, 18	12.89	34.29	6.26	3.50	0.0227	0.0284	0.0519
September, 25	12.17	34.38	6.25	3.26	0.0222	0.0257	0.0482
September, 29	10.97	34.63	6.79	3.56	0.0217	0.0254	0.0519
SEm±	0.70	--	0.11	0.09	--	0.0020	0.0022
$CD_{0.05}$	1.72	NS	0.27	0.24	NS	0.0050	0.0055

References

Arnon DI 1949. Copper enzymes in isolated chloroplasts, polyphenoxidase in *Beta vulgaris*. Plant Physiol. **24**: 1 -15.

Corbesier L, Vincent C, Jang S, Fornara F, Fan Q, Searle I, Giakountis A, Farrona S, Gissot L, Turnbull C and Coupland G 2007. FT protein movement contributes to long-distance signaling in floral induction of Arabidopsis. Science. **316**: 1030-1033.

Hartmann TH, Kester ED, Davies TF and Geneve LR 2002. *Plant Propagation*: *Principles and Practices*. Prentice Hall, New Jersey. 770 p.

Hiscox JD and Israelstam GF. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. Canadian. J. of Bot. **57**: 1332-1334

Jayawickrama KJS, McKeand SE, Jett JB, Young E. 1992. Rootstock and scion effects on carbohydrates and mineral nutrients in loblolly pine. Canadian. J. of Frst. Res. **22**: 1966–1973.

Kumar P, Rana S, Sharma P and Negi V 2015. Vegetable grafting : a boon to vegetable growers to combat biotic and abiotic stresses. Himachal J. Agri. Res. **41** (1): 1-5.

Mahunu GK, Adjei PY and Asante AK 2012. Anatomical studies on graft formation in cashew (*Anacardium occidentale* L.). Agric. and Bio. J. of North Amer. **3** (4): 150-153

Mapelli S, Kinet JM. 1992. Plant growth regulator and graft control of axillary bud formation and development in the TO-2 mutant tomato. *Plant Gr. Regul.* **11**: 385-390.

Navarro L 1988. Application of shoot-tip grafting *in- vitro* to woody species. Acta Hortic. **227**: 43-56.

Oguz Dolgun F, Ekmel Tekintas and Engin Ertan A 2008. Histological investigation on graft formation of some nectarine cultivars grafted on Pixy rootstock. World J. of Agri. Sci. **4** (5): 565-568.

Polat AA and Kaska N 1992. Determination of budding success in loquats budded on Quince-C rootstock. Bahce. **21** (1/2): 9-11.

Rana S, Kumar P, Singh A and Upadhyay 2015. Evaluation of different rootstocks for bacterial wilt tolerant in bell papper (Capsicum annum var grossum (Sendt) under protected condition. Himachal J. Agri. Res. **41** (1): 100-103.

Sharma LK and Rana RK 2015. Effect of top-working to improve the top-working in apple (Malus x domestica Borkh) orchards under mid-hill conditions of Kullu district. Himachal J. of Agri. Res. **41** (1): 89-92

Simon A, Mng'omba1 and Elsa S. du Toit 2007. Histological evaluation of early graft compatibility in *Uapaca kirkiana* muell arg. scion/stock combinations. Hort. Sci. **42**(3):732-736.

Tekintas FE 1991. An anatomical and histological investigation on graft formation in citrus species and varieties grafted on different rootstocks, 100. Yil Univ. J. Fac. Agric., Van. Turkey, **1**(2): 68-81

Tekintas FE and Doigun O 1996. An investigation on compatibility in some peach and nectarine cultivars grafted on almond seedling, 100. Yl Univ. J. Fac. Agric., 6(1): 51-54.

Unal A 1992. An investigation on anatomical characteristics of grafting in almond, plum and apricot grafted on apricot rootstocks. In: National Horticultural Congress, Izmir, Turkey, pp: 41-45.

White JW, Montes C, Mendoza LY 1992. Use of grafting to characterize and alleviate hybrid dwarfness in common bean. Euphytica. **59**:19–25.

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Short Note

Evaluation of lettuce genotypes for yield and quality under protected conditions of North-western Himalayas

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Abstract

Lettuce is a popular salad vegetable in European countries. In India its demand is also increasing. It is not possible to grow salad vegetables under open environmental conditions due to vagaries of weather. The state government in Himachal Pradesh (India) is promoting polyhouse cultivation in a very big way. But the lack of suitable cultivars under polyhouse conditions is the biggest challenge to the growers of the hilly state. Therefore, in the present study seven genotypes of lettuce *viz*. Red Butter Head (G_1), Ice-berg (G_2), Revolution (G_3)**,** Dublin (G_4), Garishma (G_5), Bergamo (G_6) and Green Romaine (G_7) were evaluated in a 36 x 6 m modified naturally ventilated polyhouse having fan pad system. Maximum gross weight (826.6 g/plant) was recorded in G_2 which was statistically at par with G_4 (791.6 g/plant). Minimum gross weight per plant was found in G_7 (18836 g). Maximum net weight/plant was recorded in G_7 (631.3 g) which was statistically at par with G_2 (578.3 g), G_4 (583.6 g), G_5 (458.6 g) and G_6 (480.3 g). Lettuce genotypes also varied in quality parameters *viz*. chlorophyll b and total chlorophyll, starch, reducing, non-reducing and total sugars and sodium content.

Key words: Lettuce, polyhouse, protected cultivation**,** salad vegetable

Lettuce (*Lactuca sativa* L), a member of family Asteracae is the most important salad crop of European countries. It also occupies an important position in tropical and subtropical countries. In temperate countries, it is mostly grown under glass and plastic structures (Santos Filho *et al*. 2009; Carlo Fallovo et al 2009). In India, it is a minor commercial crop grown on a small scale in home gardens. It is an important polymorphic plant particularly with respect to foliage characteristics. It grows to a height of 10 to 20 cm with spread of 15 to 30 cm. Lettuce is a cool season crop. The optimum mean temperature range for excellent growth and good quality of lettuce is 15–25 ^{0}C. The temperature above 25 ^{0}C accelerates seed stalk and reduces the quality of leaves. It prefers light loam or sandy loam well drained fertile soils with pH 6-8. Lettuce is a rich source of chlorophyll, water, ascorbic acid, ash, starch, sugars and sodium which are the essential components of balanced diet.

Chlorophyll is a green pigment found in most plants is one of the oldest and most widely consumed pigments in our diet. As it has been in the human diet forever, it can be considered one of the most safe food components. Although all varieties of lettuce have low calories, each variety has different nutrient content. Romaine lettuce is the most nutrient-dense of all the lettuce varieties and is an excellent source of vitamins A, B1, B2, and C, folic acid, manganese and chromium, while Iceberg lettuce variety provides a good source of choline. The outer leaves may contain fifty times more nutrients than the stem. Lettuce is a good source of chlorophyll and vitamin K, good for dieters because it is very low in calories. Lettuce is a good source of iron which is the most active element in the body. Therefore, it must be replenished frequently to meet any sudden demand of the body such as the rapid formation of red blood corpuscles in heavy loss of blood.

Magnesium content has exceptional vitalizing powers especially in the muscular tissues, the brain and the nerves. Lettuce may also help to treat acid indigestion, anemia, arthritis, catarrh, circulatory problems, colitis, constipation, cough, diabetes, gastritis, gout, insomnia, irritable bowel, obesity, sexual addiction, stress, tuberculosis, ulcers and urinary tract diseases.

In recent time people are becoming health conscious and demand for salad in food is increasing. In India protected cultivation is an emerging field and standardized package for lettuce production as well as suitable varieties/hybrids under protected conditions is scarce. In Himachal Pradesh too, polyhouse technology is becoming popular with the efforts of the state government, where 80% subsidy for construction of polyhouses is being provided by the government under "*Pandit Deen Dyal Updhyay Kisan Bagwan Samridhi Yojna*" (Pandit Deen Dyal Farmers-Horticulturists Progress Plan). Lettuce can be used as a gap crop in the polyhouses to incur more income. The lettuce is high-value, thermo sensitive vegetable crop which can be grown successfully under polyhouse conditions. However, there is no scientific information available in India on lettuce cultivation under polyhouses. The work on its quality estimation has also been limited. Therefore, the present study was conducted to evaluate different hybrids for yield and quality traits of lettuce under protected conditions.

The present investigation was undertaken at Palampur (32^0 6' N latitude, 76^0 3' E longitudes and 1290.8 m altitude) during 2009. Severe winters and mild summers with high rainfall characterize the place. Agro climatically, the location represents the mid-hill zone of Himachal Pradesh. It is characterized by humid sub-temperate climate with high rainfall (2500 mm), of which 80% is received during June to September. During October, there is no crop inside the polyhouse, therefore, to utilize the lean period, 7 genotypes *viz*. G_1 - Red Butter Head, G_2 - Green Ice-berg, G_3 - Revolution**,** G_4 -Dublin, G_5 - Garishma, G_6 - Bergamo and G_7 - Green Romaine were undertaken and planted in Randomized Block Design with 3 replications in a 36 x 6 m modified naturally ventilated polyhouse. The crop was grown on 20 cm raised bed having 70 cm width. Vermicompost (at 5 t/ha) and chemical fertilizers (60: 40: 40 kg N, P_2O_5 and K_2O/ha) were applied in pits before transplanting. Plants of each genotype were planted at inter row distance of 45 cm and intra plant distance of 30 cm. The intercultural operations i.e. hoeing and weeding were carried out in accordance with recommended package of practices to ensure a healthy crop growth and development. The observations were recorded on various yield contributing and quality traits in 5 randomly selected plants in each entry. The parameters recorded on growth and yield were: plant frame (cm^2), stem length (cm), stem diameter (cm), gross weight (g), net weight (g), polar diameter (cm), equatorial diameter (cm) and quality traits such as uniformity, heading (%), head shape, leaf colour, leaf texture, leaf shape, taste, colour of core, firmness, ascorbic acid content (mg/100 g)**,** chlorophyll 'a'/g tissue , chlorophyll 'b'/g tissue, total chlorophyll/g tissue total, moisture (%), ash (%), starch (%), total sugars, reducing sugars (%), non-reducing sugars and Na (g/100 g) following standard procedures (AOAC 1990; Hodege and Hofreiter 1962; Jayraman 1981; Miller 1972; Subbarao et al. 2003). Total chlorophyll was estimated spectrophotometrically by the method of Jayraman (1981).

Extraction of total chlorophyll was carried out in cleaned pestle and mortar by grinding fresh samples (0.2 g) with 80% acetone. The extracts were centrifuged at 4,000 rpm for 15 min and then chlorophylls were repeatedly extracted out with 20 ml (5-5 ml repeatedly, 4 times) 80% acetone until residues became colourless. Finally, the volume was made up to 20 ml with 80% acetone and absorbance was measured at 663, 645 and 480 nm with the help of ELICO (India) SL-159 UV-VIS Spectrophotometer. For the estimation of ascorbic acid (AOAC, 1990), 100 g of fresh lettuce samples were grounded with 100 ml of 2% oxalic acid as extraction medium in order to get slurry. The weight of slurry was recorded and 20 g of this slurry was taken in a beaker and its volume was made up to 100 ml with 1% oxalic acid. The content of the beaker was filtered properly through Whatman Filter paper No. 1. Charcoal treatment was given if any colour remained due to pigments. 5 ml of this filtrate was pipetted out and titrated against a dye solution (2,6 dichlorophenol indophenol) prepared by taking 52 mg of dye in 200 ml volumetric flask adding 100 ml of hot distilled water. The volume was then made to 200 ml with distilled water. After cooling 42 mg of $NaHCO_3$ was added and dissolved properly. At the same time 100 mg of ascorbic acid was dissolved in 500 ml of 1% oxalic acid solution was used as standard (always prepared fresh). Moisture content in the lettuce was determined by following the oven drying method. Estimation of starch was done by anathrone reagent method by using various reagents such as: 0.1 to 0.5 g of the sample homogenized in hot 80% ethanol to remove sugars, centrifuged and retained the residue, washed the residue repeatedly with hot ethanol (80%) till the washings did not give colour with anthrone reagent and dried the residue over a water bath. To the residue 5.0 ml of water and 6.5 ml of

52% perchloric acid were added. Extracted at 0 ^{0}C for 20 minute with centrifuge and sage the supernatant; repeated the extraction using fresh perchloric acid. Centrifuged and poured the supernatants and made up to 10 0ml. 0.1 or 0.2 ml of the supernatant was piped out and made up the volume to 1 ml with water. Prepared the standards by taking 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard and made up the volume to 1 ml in each tube with water. Added 4 ml of anthrone reagent to each tube and heated for eight minutes in a boiling water bath. Cooled rapidly and read the intensity of green to dark green colour at 630 nm. The glucose content in the sample was noted by using the standard graph and multiplied with the value by a factor 0.9 to arrive at the starch content. The estimation of reducing sugar was carried out by dinitrosalicylic acid method**.** Dissolved by stirring 1 g dinitrosalicylic acid, 200 mg crystalline phenol and 50 mg sodium sulphite in 100 ml 1% NaOH and stored at 4^{0}C. Since the reagent deteriorates due to sodium sulphite, it may be added at the time of use if long storage is required. Followed steps 1 to 3 as in Nelson -Simonyi's method to extract the reducing sugars from the test material. Piped out 0.5 to 3 ml of the extract in test tubes and equalized the volume to 3 ml with water in all the tubes. Added 3 ml of DNS reagent and heated the contents in a boiling water bath for 5 min. When the contents of the tubes were still warm, 1 ml of 40% Rochelle salt solution was added. Cooled and read the intensity of dark red colour at 510 nm. Run a series of standards using glucose (0 to 500 mg) and plot a graph. Calculated the amount of reducing sugars in the sample, using the standard graph. The concentration of non reducing sugar was determined as the differences in the concentration of total sugars and reducing sugar.

Mineral content in lettuce genotypes was estimated with standard procedure by using 3 g of dried and finely ground sample in 100 ml Kjeldahl flask. 25 ml of mixture of concentrated HNO_3, concentrated $HClO_3$ and concentrated H_2SO_4 was added in ratio of 3:2:1 and shaked well so that no dry lumps were left behind. A clean acid washed glass bead was dropped into flask to avoid bumping during digestion. This flask containing sample was allowed to stand for 3-4 hours in a fume cupboard. Then this was heated on digestion heater and was watched out for foaming during the first hour. In case of excessive foaming which tends to overflow, the bulb of flask was immersed in cold water till the digestion was completed. Then it was allowed to cool and the digested samples were filtered through Whatman filter paper No. 40 into a 100 ml volumetric flask. It was made sure that contents of digestion flask were quantitatively transferred by rinsing the flask 3-4 times with deionized water. The silica residue was washed on filter paper with dilute HCl (1: 19) in order to wash down salts completely. The volume of collected filtrate was made 100 ml. This mineral solution was transferred in pre acid washed polythene bottles and stored in a cool place till use. Mineral sodium was analyzed in 100 ml of ash solution. Sodium and potassium were estimated by Flame Photometry using Systronics-129 Flame Photometer. Dilutions, where required were made with double distilled water and dilution factor were incorporated in final calculations.

The data on yield contributing characters and yield are summarized in Table 1.

Table 1. Effect of genotypes on **y**ield contributing characters and yield of lettuce

Genotypes	Plant frame (cm^2)	Stem length (cm)	Stem diameter (cm)	Gross weight (g/plant)	Net weight (g/plant)	Polar diameter (cm)	Equatorial diameter (cm)
Red Butter Head (G_1)	535.0	4.3	2.5	373.3	294.0	13.7	10.8
Ice-berg (G_2)	1111.7	3.7	2.6	826.7	578.3	12.3	11.2
Revolution (G_3)	794.0	3.3	1.8	188.7	206.7	20.3	12.3
Dublin (G_4)	845.0	3.9	2.3	791.7	583.7	12.0	10.7
Garisma (G_5)	970.3	3.5	2.5	682.0	458.7	12.2	11.7
Bergamo (G_6)	874.3	3.5	2.3	509.7	480.3	17.7	18.3
Green Romaine (G_7)	1137.0	3.7	2.5	656.0	631.3	30.0	20.7
LSD (P=0.05)	NS	NS	NS	152.9	175.7	4.5	5.9
CV (%)	25.9	23.4	16.5	14.8	21.1	14.7	24.2

Plant frame, stem length and stem diameter though shown wide variation under genotypes but were not affected significantly as having greater CV values. However, gross and net green weight/plant varied significantly due to genotypes. Maximum gross weight (826.6 g/plant) was recorded under G_2 (Green Ice-berg) which was statistically at par with G_4 (Dublin) (791.6 g/plant). Minimum gross weight per plant was found in G_3 (Revolution) (188.6 g/plant). Maximum values of net weight were recorded in G_7 (Green Romaine) (631.3 g/plant) which was statistically at par with G_2 (Green Ice-berg) (578.3 g/plant), G_4 (Dublin) (583.6 g/plant), G_5 (Garishma) (458.6 g/plant) and G_6 (Bergamo) (480.3 g/plant). Polar and equatorial diameter were also significantly varied due to genotypes. Highest polar diameter (30 cm) was recorded in G_7 (Green Romaine) whereas, it was lowest in G_5 (Garishma) (12.16 cm). Similarly equatorial diameter was maximum (20.6 cm) in G_7 (Green Romaine) and lowest in G_4 (Dublin) (10.6 cm) (Table 1).

Various morphological quality parameters studied are shown in Table 2. All the genotypes were uniform in growth. There were three types of genotypes under investigation *viz*; heading, semi heading and leafy. Heading percentage was uniform and its shape was round in all heading genotypes. The leaf colour varied and all the genotypes have different leaf colour. G_1 (Red Butter Head) was reddish tinged green, G_2 (Green Ice-berg) having petiole white, G_3 (Revolution) purple, G_4 (Dublin) and G_5 (Garishma) light green, G_6 (bergamo) yellowish green and G_7 (Green Romaine) was dark green. Colour of the core was also different in all the genotypes. Genotype G_1 (Red Butter Head) had yellow core, G_2 (Green Ice-berg) with yellow green, G_3 (Revolution) having purple with greenish tinge, G_4 (Dublin) white yellowish and G_5 (Garishma), G_6 (Bergamo) and G_7 (Green romaine) had white green core (Table 2). Leaf texture was smooth in G_1 (Red Butter Head) and G_4 (Dublin), having serrated leaves in G_2 (Green Ice-berg) and G_3 (Revolution), toothed margin leaves in G_5 (Garishma); G_6 (Bergamo) had fan type leaves and G_7 (Green Romaine) was non heading open type. All the genotypes were sweet in taste except G_6 (Bergamo) and G_7 (Green Romaine) which were slightly bitter.

Among the quality characteristics, chlorophyll 'a'/g tissue, ascorbic acid and Ash % did not exhibit significant differences due to genotypes under polyhouse conditions (Table 3). Highest chlorophyll 'b'/g tissue was estimated in G_3 (Revolution) (0.237), followed by G_6 (Bergamo) (0.187), G_7 (Green Romaine) (0.170) and G_1 (Red Butter Head) (0.159) which were statistically at par. Its lowest

Table 2: Morphological quality parameters of the various genotypes

Genotype	Uniformity	Heading (%)	Head shape	Leaf color	Leaf texture	Leaf shape	Taste	Color of core	Firmness
Red Butter Head (G_1)	Uniform	100	R	Reddish tinged green	Smooth	Oblong	Sweet	Yellow	Slightly loose
Ice-berg (G_2)	Uniform	100	R	Petiole white	Serrated leaves	Fan type	Sweet	Yellow green	Compact
Revolution (G_3)	Uniform	Leafy	-	Purple	Serrated leaves	Fan type	Sweet	Purple with greenish tinge	Loose
Dublin (G_4)	Uniform	100	R	Light Green	Smooth	Fan type	Sweet	White yellowish	Compact
Garisma (G_5)	Uniform	100	R	Light Green	Toothed margins of leaves	Round	Sweet	White Green	Compact
Bergamo (G_6)	Uniform	Leafy	-	Yellowish green	Puckered leaves smooth	Fan type	Slightly bitter	White Green	Loose
Green Romaine (G_7)	Uniform	Leafy	-	Dark Green	Smooth	Non heading open	Slightly bitter	White Green	Loose

Table 3. Genotype effect on quality in lettuce

Genotypes	Chloro-phyll 'a'/ g tissue	Chloro-phyll 'b'/ g tissue	Total chloro-phyll / g tissue	Mois-ture %	Ascorbic acid mg/100g	Ash %	Starch %	Reducing sugar %	Non reduc-ing sugar %	Total sugar %	Na mg/100g
Red Butter Head (G_1)	0.231	0.159	0.390	95.5	5.8	7.37	15.5	1.78	3.40	5.09	32.3
Ice-berg (G_2)	0.030	0.047	0.079	97.6	7.7	6.17	14.5	1.58	2.38	3.96	31.6
Revolution (G_3)	0.255	0.237	0.491	94.9	7.5	11.2	3.5	0.51	0.67	1.18	33.6
Dublin (G_4)	0.191	0.057	0.098	97.0	7.6	5.0	14.0	1.09	2.82	3.58	32.7
Garisma (G_5)	0.082	0.090	0.172	96.7	9.4	8.2	19.4	2.04	2.41	4.45	32.3
Bergamo (G_6)	0.148	0.187	0.302	94.9	6.7	10.2	5.8	1.67	3.17	4.84	34.4
Green Romaine (G_7)	0.319	0.170	0.488	93.2	8.8	7.8	15.9	1.19	2.81	3.99	32.2
LSD (P=0.05)	NS	0.117	0.139	2.1	NS	NS	1.8	0.24	0.68	0.56	1.4
CV (%)	59.3	48.2	26.8	1.2	20.9	30.2	7.7	9.4	15.1	8.1	2.4

value (0.057) was recorded in G_4 (Dublin). Total chlorophyll was highest (0.491/g tissue) in G_3 (Revolution) which was statistically at par values with G_7 (Green Romaine) (0.488) and G_1 (Red Butter Head) (0.390). Moisture % varied in different genotypes. It was significantly higher in G_2 (Green Ice-berg) (97.64%) being at par with G_4 (Dublin) (96.69%) and G_5 (Garishma) (96.68%). Starch percentage (19.35%) and reducing sugar (2.043%) were highest in G_5 (Garishma). Whereas genotype G_3 (Revolution) resulted in lowest values of starch (3.54%) and reducing sugars (1.183%). Non reducing sugars were maximum in G_1 (3.403%). These were minimum in G_3 (Revolution) (0.673%). Total sugar percentage exhibited significant variation. Its maximum values were found in G_1 (Red Butter Head) (5.090%). It was lowest in G_3 (Revolution) (1.183%). Sodium was maximum in G_6 (Bergamo) (34.42 mg/100g). Its minimum value was found in G_2 (Green Ice-berg) (31.50 mg/100g). Similar studies were also undertaken by Dolma and Gupta (2011) and Gupta *et al*. (2009).

References

AOAC. 1990. Official Methods of Analysis of the Association of Official Analytical Chemists, 11th edition, Washington D. C.

Carlo Fallovo, Youssef Rouphael, Mariateresa Cardarelli, Elvira Rea, Alberto Battistelli and Giuseppe Colla. 2009. Yield and quality of leafy lettuce in response to nutrient solution composition and growing season. Journal of Food, Agriculture & Environment 7 (2) : 4 5 6 - 4 6 2 .

Dolma T and Gupta AJ. 2011. Evaluation of Lettuce Genotypes for Growth and Yield Attributes in Kashmir Valley. *Indian Journal of Plant Genetic Resources* 24(1).

Gupta AJ, Tashi Dolma, Khan SH and Jabeen N. 2009. Studies on Yield Contributing Parameters in Lettuce (*Lactuca sativa L.*). *Indian J. Ecol.* 36(2): 131-134.

Hodege JE and Hofreiter BT. (1962). In: Methods in Carbohydrate Chemistry (Eds Whistler, RL and Be Miller JN), Academic Press New York.

Jayraman J. 1981. Laboratory manual in biochemistry. Willay Eastern Pvt Ltd, New Delhi.

Miller GL. (1972). Anal Chem. 31, 426.

Santos Filho BG, Lobato AKS, Silva RB, Schimidt D, Costa RCL and Alves GAR. 2009. Growth of Lettuce *(Lactuca Sativa* L.) in Protected Cultivation and Open Field. *Journal of Applied Sciences Research, 5(5): 529-533*

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Short Note

Surgical removal of lingual foreign body in a buffalo - a clinical case study

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Abstract

This report pertains to a successful surgical removal of a sewing needle that was ingested by an eight years old buffalo. The animal was not able to ingest anything after the needle ingested. The radiographic examination on lateral and dorsal-ventral views revealed the presence of the needle in the sub mandibular area. After preparing the animal for operation, the genioglossus muscle was incised. The foreign body was reached which was too sharp and move along with movement of tongue. A flat instrument was put in the oral cavity to stabilise the tongue. The foreign body was then removed with help of long artery forceps. Antiseptic dressing with ointment Neosporin and topicure spray locally was advised till the complete healing of the wound. Retrieval of the needle seems easy but it was still difficult as it was embedded in genioglossus muscle and was moving along with the movement of tongue.

Key words: Buffalo, foreign body, radiographic examination, genioglossus muscle, surgical retrieval

Cattle commonly ingest foreign objects, because they do not discriminate against metal materials in feed and do not completely masticate feed before swallowing. Consequently foreign bodies struck in reticulum. They may cause diaphragmatic hernia (Krishnamurthy *et al*. 1985) and foreign body syndrome in bovines (Kohli *et al*. 1982). But oral foreign bodies are rarely found and if so they are commonly found in Esophagus. The present case pertaining to a buffalo which ingested a sewing needle that was embedded in genioglossus muscle and was moving along with the movement of tongue.

An 8 year old buffalo was presented with the history of eating sewing needle a day earlier. Since then the animal was not able to ingest anything. The radiographic examination on lateral and dorsal-ventral views (Plate A and B) revealed the presence of linear foreign body in the sub mandibular area. Surgical removal of the foreign body was planned. Preoperatively the animal was given injection xylazine 20 mg I/M along with injection meloxicam 0.2 mg/kg Body Weight I/M and injection dicrysticine 2.5 g I/M [Streptomycin Sulphate: 2.5 g, Procaine Penicillin G: 15,00,000 units, Penicillin G Sodium: 5,00,000 units].

The animal was restrained in lateral recumbency on a padded large animal operation table. The site was prepared for surgery by shaving the submandibular and mandibular area and scrubbing was done with antiseptic solution containing cetrimide. Then local anaesthetic (lignocaine HCL 2%) was infiltrated (20 ml) within the skin and muscles around the foreign body. Thereafter, the incision was made on mid-ventral aspect of submandibular area. Digital palpation of area did not revealed any sharp foreign body. The genioglossus muscle was incised and the foreign body was reached which is to sharp and move along with movement of tongue. Afterwards a flat instrument was put in the oral cavity to stabilise the tongue. The foreign body was then removed with help of long artery foreceps. The muscles were sutured with polyglactin 910 (No. 2-0) in simple continuous pattern. The skin was sutured with polypropylene (No. 1-0)

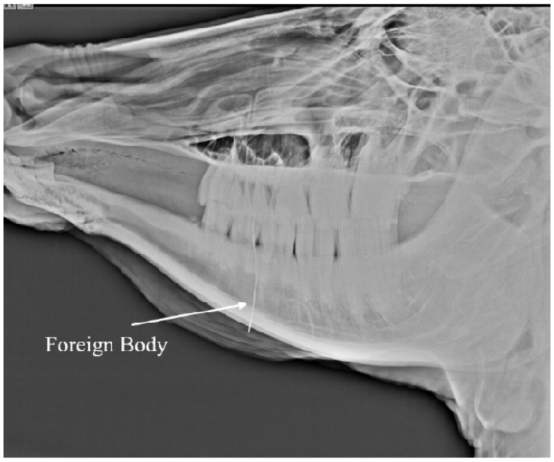

Plate A. Linear Foreign Body in lateral Radiograph

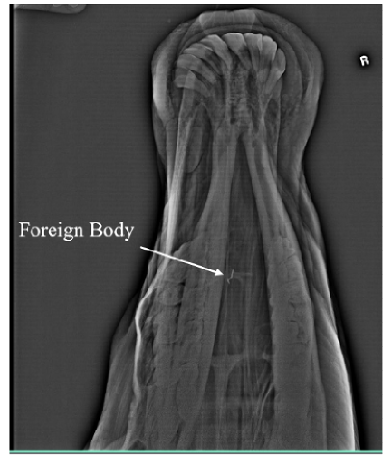

Plate B. Linear Foreign Body in dorso-ventral Radiograph

in horizontal mattress pattern. Postoperatively, the buffalo was given injection dicrysticine 2.5 g I/M bid and meloxicam 0.2 mg/kg Body Weight I/M bid, belamyl 10 ml I/M sid [Thiamine hydrochloride: 10 mg, Riboflavin: 3 mg, Niacinamide: 100 mg, Vitamin B 12: 10 mcg, Liver injection crude: 0.66 ml (having Vitamin B 12 activity equivalent to 2 mcg of Cynocobalamin per ml), Phenol: 0.5%] for 5 days. Antiseptic dressing with ointment Neosporin and topicure spray locally was advised till complete healing of the wound.

Retrieval of oral foreign body (sewing needle) in present case, seems easy to perform but it was still difficult as it was embedded in genioglossus muscle and was moving along with the movement of tongue and its retrieval was not possible till the tongue was stabilised by some flat surgical instrument.

References

Krishnamurthy D, Nigam JM, Peshin PK, Sharma DN and Tyagi RPS. 1985. Monograph of diaphragmatic hernia in bovines. Harayana Agricultural University, Hisar.

Kohli RN, Kumar R, Sobti VK, Singh J, Prasad B and Sharma SN. 1982. Diagnosis of foreign body syndrome in bovines. Modern Veterinary Practice. **63**, 501.

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