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INTEGRATED WEED AND NUTRIENT MANAGEMENT FOR ENHANCING GROWTH, YIELD, AND WEED DYNAMICS IN BARLEY (*HORDEUM VULGARE* L.): A REVIEW

Nilotpal Das[1], Meka Shivaram Reddy[2], Ashok S. Dambale[3], Akashdeep Singh[4], Digvijay Singh[2], Vishal Prajapati[2], Ankit Saini[4*] and Chinmaya Sahoo[2*]

[1]Department of Agronomy, Palli Siksha Bhavana, Visva-Bharati University, Sriniketan–731236, West Bengal, India,

[2]Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar-848125, India

[3]Department of Agronomy, School of Agriculture, Lovely professional University, Phagwara, Punjab -144411, India

[4]Department of Agronomy Dr Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur, HP-173101, India

*Corresponding authors E-mail: chinmaya97sahoo@gmail.com ; ankitsaini9770@gmail.com

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ABSTRACT

An experimental field study was carried out to assess how such practices as integrated weed and nutrient management practices affect barley (*Hordeum vulgare* L.) growth, yield, and the dynamics of the weed. The objective of the study was to find the best mixture of weed management and nutrient application options to promote crop production and sustainability. The treatments involved the various methods of weed management, such as pre- and post-emergence herbicides, hand weeding, and a combination of techniques, with nutrient management techniques such as inorganic fertilizers, organic manures, and a combination of both. The findings showed that integrated weed and nutrient management had a considerable impact on the crop growth parameters, yield characteristics, and weed flora composition. The integrated treatments were effective in decreasing the level of weed density and the accumulation of dry matter, resulting in more nutrient uptake and also efficiency in resource utilization. The balanced fertilization and the application of herbicides at the right time and manual weeding led to an increase in the yield of grain and straw, as opposed to the other management practices. In addition, combined methods enhanced the fertility conditions of soils and maintained the production of crops in the long run. The research underscores the fact that the application of an integrated weed and nutrient management program is critical to attain large yield potential and ecological stability in barley-based systems of cropping systems. These practices not only increase productivity but also facilitate environmentally friendly and sustainable crop management practices that are appropriate in the current agriculture.

***Keywords*:** Barley, combined management of nutrients, weed management, crop productivity, sustainability, herbicides, soil fertility.

Introduction

India is a majorly agricultural-dependent economy, and the agricultural economy also plays a huge role in the national GDP, taking the second position after the service sector, about 14.7 percent in 2016. Through agriculture, the country not only supplies food to the population but also it also provides jobs to almost 57 percent of the Indian population. Barley (*Hordeum vulgare* L.) holds the fourth position among the most significant and the oldest among the cultivated crops in the world and has been utilized since biblical times as food, feed, and others. Barley is a very nutritious and easily digestible cereal that has approximately 8-10 percent protein, 69.6 percent carbohydrates, 1.3 percent fat, 3.9 percent crude fiber, 1.5 percent ash, 26 mg of calcium, and 215mg of phosphorus, and offers approximately 336 kcal energy per 100g. It also contains a lot of vitamin B-complex and is usually used to make traditional foods like chapati and sattu. Barley is also mostly planted in marginal and sub-marginal terrains of light-textured soils of low nitrogen, organic matter, and moisture holding capacity. Barley occupies an area of approximately 51.50 million hectares, and the total production is 142.01 million metric tonnes all around the world. In India, in 2016-17, it was planted on 7.72 lakh hectares, and generates about 17.26 lakh tonnes of grain with an average yield of 2522 kg/ha (Anonymous, 2017). But the average yield in India is still much less than the achievable yield potential of 4050 q/h (Choudhary *et al*., 2014). One of the significant limitations in the production of barley is the infestation of weeds. Weeds outcompete the crops in terms of such basic resources as nutrients, water, light, and space, thus lowering yield, compromising quality, and raising the cost of production. In India, weeds cost about 1650 crores (Joshi, 2002) annually; this is more than the losses incurred by insect pests and diseases. It is believed that one kilogram of biomass of weeds produces an effect of about one kilogram due to the barley yield (Chaudhary *et al*., 2008). The problem of weeds has been worsened by the introduction of high-yielding dwarf varieties with high nutrient demand, which have provided good grounds for the growth of the weeds, especially *Phalaris minor* and *Avena* spp. (Gill *et al*., 1984). The weeds that are normally found in barley fields include grassy weeds (*Phalaris minor*, Avena ludoviciana) and the broad-leaved weeds like *Chenopodium album, Fumaria parviflora, Melilotus indica, Anagallis arvensis, Cirsium arvense, Lathyrus aphaca* and *Vicia sativa* (Malik *et al*., 1993). The cost of labor and the unavailability of farm inputs are leading farmers to trend towards the use of herbicides to control weeds. Nevertheless, the constant application of herbicides has resulted in a change in the weed flora and the development of herbicide resistance. Thus, it is necessary to establish novel herbicide combinations that possess varied modes of action to tackle weeds. Combining herbicides not only increases the range of herbicides but also contributes to the resistance becoming slower (Valverde, 2003; Das, 2008). However, post-emergence herbicides may occasionally result in phytotoxicity, e.g., in barley leaf scorching or discolouration. Previously, dwarf varieties of barley using fertilizer and new varieties were more vulnerable to grass weeds such as *Phalaris minor* and *Avena ludoviciana* because broadleaf weeds were the dominant ones before the green revolution (Singh *et al*., 1995). With good management of weeds, a great potential would be to boost national crop production; it could increase the production of food grains, pulses, oil seeds, and commercial crops by 103 million, 15 million, 10 million, and 52 million tonnes per year, respectively (NRCWS, 2007). This will add an increment of approximately 105000-36crores of income annually, but approximately 100 billion is already expended on weed control in Indian agriculture each year (Varshney & Prasad Babu, 2008). Nutrient control is crucial for growth, productivity, and quality of barley. The crop is also very sensitive to external nutrient application, especially nitrogen, which is mostly lacking in soils in barley-growing areas. Nitrogen fertilization increases the level of dry matter accumulation, root development, and output of grains, besides producing organic residues that increase soil fertility. Phosphorus and potassium are also necessary and should be incorporated using the fertilizer or manure to have balanced nutrition. Farmyard manure (FYM), compost, and vermicompost, as organic manures, are becoming increasingly significant as cost-effective sources of nutrients that are environmentally friendly. The mixed application of organic and inorganic fertilizers enhances soil structuring, efficiency of nutrient utilization, and quality of crops at the expense of lower costs of production. Integrated nutrient management (INM) is a management approach that corrects secondary and micronutrient deficiencies in addition to discussing the macronutrient needs (Tripathi *et al*., 2010). Organic sources have an additive effect when used together with the chemical fertilizers, as opposed to when they are used separately (Palaniappan and Annadurai, 2007). This type of integration improves the health of the soil, maintains extended productive outcomes, and reduces the adverse effects of overuse of chemicals as fertilizers (Babu *et al*., 2007). Excessive use of high-analysis fertilizers has resulted in soil erosion and stagnation in the yield of barley. Hence, a combination of inorganic and organic alkalinity and vermiculite manures like FYM and vermicompost with the suggested amounts of inorganic fertilizers is a viable approach to sustainable barley production due to the increased soil fertility, cycling of nutrients, and productivity.

Effect of weed management

Weed Flora in Barley

The practice of barley growth is seen in some of the large states in India, such as Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, and Gujarat. Weed flora composition in barley fields can be significantly different across regions since the edaphic and climatic conditions are different. A certain type of weed can be very troublesome in one environment and not in the other. *Phalaris minor, Avena ludoviciana, Avena fatua, Chenopodium album, Melilotus alba, Melilotus indica, Anagallis arvensis, Asphodelus tenuifolius, Coronopus didymus, Lathyrus aphaca, Medicago denticulata, Medicago hispida, Cirsium arvense, Cynodon dactylon, Cyperus rotundus, Rumex* *dentatus, Spergula arvensis* and *Trifolium flag*. Howalt (2005) noted that carfentrazone could be used as a safener to minimize the damage caused to the crop, or it could be used with sulfonylurea herbicides. One of the broad-leaved weeds, like *Malva parviflora* and *Convolvula arvensis*, can not be effectively controlled using 2,4-D or metsulfuron, but can be effectively controlled using carfentrazone. Pandey *et al.* (2006) indicated that the use of sulfosulfuron and metribuzin has a drastic effect to reduce barley field density in the winter seasons of 200001 and 200102. Metribuzin and, more so, the sulfosulfuron used at 40 DAS were very effective in controlling *Melilotus indica* and *Phalaris minor*. Likewise, Pandey *et al.* (2007) determined that the barley fields were also characterised by the prevalence of broad-leaf weeds (e.g. *Chenopodium album, Convolvulus arvensis, Anagallis arvensis, Melilotus indica, Fumaria parviflorum, Launaea pinnatifida, Nicotiana plumbaginifolia, Spergula arvensis* and *Cannabis sativa*) whereas narrow-leaf weeds (e.g. *Phalaris minor*, The field studies conducted by Singh *et al.* (2007) in 2006-07 and 2007-08 at CCS Haryana Agricultural University, Hisar, showed a mixed infestation of grasses and broad leaved weeds dominated by *Melilotus indica, Chenopodium album, C. murale, Euphorbia helioscopia, Anagallis arvensis, Convolvulus arvensis, Rumex dentatus, Asphodelus tenuifolius, Cirsium arvense*, According to Andreasen *et al.* (2009), in winter barley, Avena spica-venti already became one of the most prominent grass weeds, and Chenopodium bursa-pastoris was also growing significantly. Punia *et al.* (2009) found *Phalaris minor, Asphodelus tenuifolius, Chenopodium album* and *Trigonella polyceratia, Chenopodium murale*, and *Avena sterilis* subsp. *Ludoviciana* and *Fumaria parviflora* are the most aggressive and dominant weed species in barley. *P. minor* was more dominant in Hisar and Fatehabad, whereas *C. album* and *C. murale* were more common in Bhiwani. On the same note, Ram *et al.* (2009) have found mixed barley infestation with *Avena ludoviciana, Phalaris minor, Chenopodium album, Lepidium sativa* and *Anagallis arvensis*. The common grassy weeds identified by El-Metwally (2010) included *Phalaris paradoxa, Avena fatua* and *Poa annua*, whereas the predominant broad-leaf weeds were *Medicago polymorpha* and *Chenopodium album.* Kumar *et al.* (2010) noted that the barley fields suffered infestation of grassy (51) and broad-leaf (49) weeds, mostly of *Phalaris minor, Avena ludoviciana, Chenopodium album*, and *Melilotus indica*. Among 136 species of weeds identified, 88% were dicotyledonous, and 78% were annual or biennial.

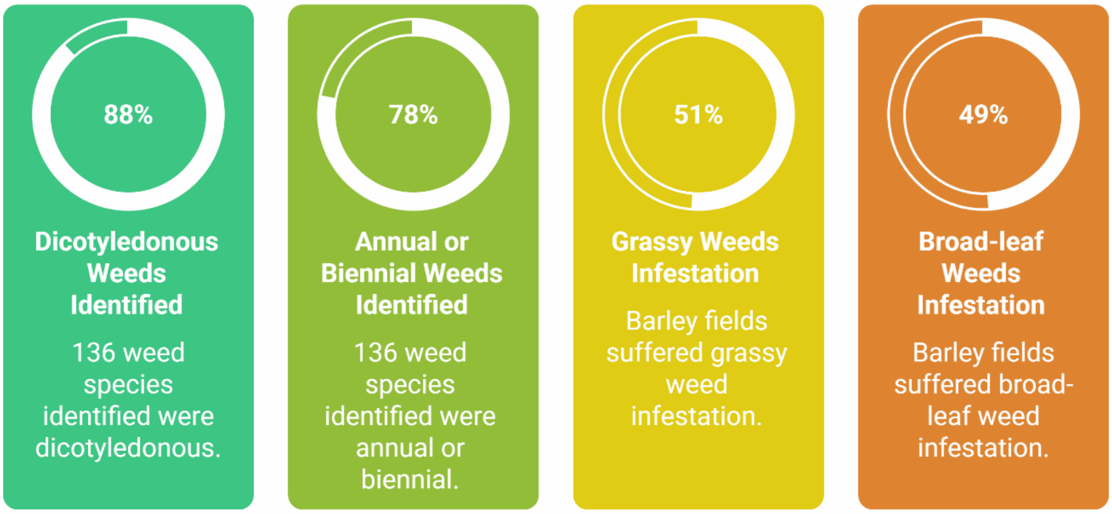

Fig. 1: Weed Flora in Barley Fields

Georgiev *et al*. (2011) documented the following most common weeds in barley as *Veronica hederifolia, Chenopodium album, Convolvulus arvensis* and *Avena fatua*. According to Bhullar *et al.* (2013), *Rumex dentatus, Medicago polymorpha, Chenopodium album* and *Anagallis arvensis* were the dominant broadleaf weeds. Likewise, *Anagallis arvensis, Avena fatua, Chenopodium album, C. murale, Cirsium arvense, Melilotus alba, M. indica, Euphorbia helioscopia, Spergula arvensis, Rumex dentatus, Asphodelus tenuifolius, Lathyrus aphaca, Vicia sativa, Phalaris minor* and *Avena ludoviciana* were documented as the major species of weed that infested the barley fields (Kumar *et al* Negi *et al.* (2015) discovered the barley was infested by grassy and broadleaf weeds, the most common of which include *Avena ludoviciana, Phalaris minor, Melilotus indica, Chenopodium album, Fumaria parviflora* and *Cyperus rotundus*. The most prevalent of them were *Avena ludoviciana* and *Melilotus indica*. *Phalaris minor* and *Chenopodium album* were the most overwhelming species reported according to Husain *et al*. (2015) and are followed by *C. rotundus, Asphodelus tenuifolius, Melilotus indica, Portulaca oleracea* and *Convolvulus arvensis*. Alshallash *et al*. (2015) compared the herbicide activities against the Italian ryegrass (*Lolium multiflorum*) in barley and revealed that isoproturon was not as effective, with more than 30 percent of weed plants surviving in various doses, but barley plants were not affected. According to Khippal *et al.* (2016), tank-mixing pinoxaden (40 g ha^{-1}) with metsulfuron (4 g ha^{-1}) and carfentrazone (20 g ha^{-1}) caused a considerable decrease in the weed dry weight as opposed to individual cases. The researchers proposed that the most prevalent weed species found in barley fields are *Avena ludoviciana, Phalaris minor, Chenopodium album, Rumex dentatus, Euphorbia helioscopia, Anagallis arvensis, Convolvulus arvensis, Melilotus indica, Cirsium arvense, Lathyrus aphaca* and *Vicia sativa* (Singh *et al*., 2017).

Effect on Nutrient Content, Uptake, and Quality

According to Bauer *et al.* (1987), the application of nitrogen (N) should be at the time of maximum crop uptake, that is, the time between the onsets of the elongation phase up to heading, with optimum uptake occurring during the flag leaf extension phase. Narolia (2009) argued that nitrogen is crucial in the generation and translocation process of carbohydrates, fatty acids, glyceroids, and other crucial intermediate products. It also affects the seed plumpness, malting quality, and the protein content of barley. According to Brady and Well (2003), potassium is a chemical traffic policeman, which is a root booster, stalk strengthener, food former, sugar and starch carrier, protein builder, respiration, water stretcher, and disease retardant-thereby increasing the quality of grains. According to Patel *et al*. (2012), total N, phosphorus (P), and potassium (K) uptake by the crop and nutrient loss by weeds were also significantly greater when 150kg N ha^{-1} was used to fertilize the crop than the recommended dose of nitrogen (RDN) of 120kg N ha^{-1}. Equally, post-harvest N status in soil with 150 kg N ha^{-1} was better than 120 kg N ha^{-1}, but the P_2O_5 and K_2O status in soil were found to be high with 150 kg N ha^{-1}. Weedy check treatment indicated reduced total N, P, and K uptake by the crop and an increase in the uptake of the nutrients by weeds. It was found that the barley varieties did not differ significantly in NPK content of grain and P and K content of straw (Ram and Dhaliwal, 2012). Nevertheless, the straw of the variety RD 2552 contained a considerably larger amount of N than the straws of RD 2035 and RD 2786. According to Jain *et al*. (2014), the uptake of N, P, and K by barley was higher with the 2,4-D treatment of clodinafop compared to isoproturon, clodinafop, and weedy check. The purpose of Shejbalova *et al*. (2014) was to assess the efficiency of nitrogen emitted by organic and mineral fertilizers used to plant spring barley during 16 years and in two sites in the Czech Republic under different soil and climatic conditions. This experiment determined dry matter yield, N content, and N uptake and the efficiency of N utilization (NUtE, kg kg^{-1}), recovery efficiency of applied N (percent), agronomic efficiency of applied N (kg kg^{-1}), and total N balance (Sigma Delta N, kg ha^{-1}). According to Sant Bahadur Singh (2017), the highest protein level was noted in barley grain (11.1) and straw (3.4) using 100 percent of NPK. A combination of chemical fertilizers and farmyard manure (FYM) enhanced the level of starch in the grain, with the highest percentage of 54% recorded under 75 percent NPK + 5 t FYM ha^{-1} + biofertilizer. This integrated treatment was found to positively correlate with the uptake of N, P, and K by grain and straw and their production. Findings revealed that the 100% NPK + 5 t FYM ha^{-1} was the best nutrient management method that was used to increase the accumulation of available N, P, and K in the post-harvest soil. Mali *et al*. (2017) demonstrated that the RD 2552 variety had a high NPK uptake by grain, straw, and total uptake. PNMP4 treatment increased considerably the N content of grain and straw, and P content was the greatest in PNMP5. Both PNMP4 and PNMP5 treatments had high NPK uptake by grain, straw, and overall uptake, which was significantly higher than in other precision nutrient management practices. Woubsh *et al*. (2017) have established that the use of lime significantly raised the pH of the soil by 3.80 to 6.63 to 6.86. There were also significant ($p < 0.05$) improvements in yield and yield components of barley as a result of the combined application of lime, blended fertilizer, and compost. The best yield (5386 kg ha^{-1}) and the nutrient uptake-N (74 kg ha^{-1}), P (19.65 kg ha^{-1}), K (16.05 kg ha^{-1}), and S (15 kg ha^{-1}) was attained when the 611 kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl + 72 kg N ha^{-1} was applied.

Effect of Weed Management Practices on Nutrient Losses by Weeds in Barley and Wheat

A number of studies have established that the nutrient uptake, losses, and yield performance of barley and related cereal crops are greatly affected by the weed management practices. According to Mukhopadhyay and Bera (1980), the yield losses caused by the weed infestation of barley and wheat ranged between 10 -52, which is dependent on the weed species, intensity, period of competition, and climatic conditions. According to Singh *et al.* (2003), the application of 2,4-D at a rate of 1 kg ha^{-1} was efficient in lowering nitrogen and phosphorus uptake by weeds and resulted in an increased nutrient uptake and protein content of the barley grains and flag leaves. In their study, Brar and Walia (2008) discovered that post-emergence herbicides like clodinafop (60 g ha^{-1}), sulfosulfuron (25 g ha^{-1}), and mesosulfuron + iodosulfuron (14.4 g ha^{-1}) had significant effects in reducing dry matter plus nutrient uptake by *Phalaris minor*, and all treatments were significantly better than the unweeded control. Likewise, Chopra *et al.* (2008) found that the effect of fenoxaprop-p-ethyl + carfentrazone-ethyl, 2,4-D, and metsulfuron-methyl in the reduction of nitrogen and phosphorus depletion decreased by 54-87 and 44-83 percent, respectively, in comparison to the weedy check, and the highest nutrient uptake and grain quality was obtained by the fenoxaprop + carfentrazone combination. Increasing the levels of weed competition (0-128 plants/L) with *Chenopodium album, Phalaris minor, Avena ludoviciana* and *Lolium temulentum* decreased the yield by 31-36 percent as the species absorbed fewer nutrients (Dodamani and Das, 2009). Tuti and Das (2011) further added that in the weedy check conditions, the weeds exploited 25.5 kg N, 12.0 kg P, and 20.9 kg K ha^{-1}, which implies that the nutrients lost in the system were high. Puniya *et al.* (2015) observed that two hand-weedings or carfentrazone-ethyl (15 g ha^{-1} at 30 -35 DAS) and 30 kg N ha^{-1} paralleled agronomic efficiency (16.2 kg grain/kg N) and nitrogen recovery (69.1%), whereas carfentrazone-ethyl was found to increase physiological nitrogen use efficiency at Jobner. Similarly, Kumar *et al.* (2017) have found that minimum removal of N and P happened with less than two hand-weedings; meanwhile, on weedy checks, maximum nutrient depletion was registered, and there were significant interactions between residue and weed management in barley.

Table 1: Effect of Weed Management Practices on Nutrient Losses by Weeds in Barley and Wheat

Researcher(s) & Year	**Crop & Location**	**Weed Management Practice**	**Dominant Weed Species / Weed Type**	**Effect on Nutrient Losses or Uptake**	**Remarks / Key Findings**
Mukhopadhyay & Bera (1980)	Barley & Wheat	General observation	Various species	Yield losses due to weeds: 10–52%	Losses depend on weed type, intensity, duration of competition, and climate.
Singh *et al.* (2003)	Barley	2,4-D @ 1 kg ha^{-1}, weed-free, weedy check	Mixed weed flora	2,4-D reduced N & P uptake by weeds; increased nutrient uptake by crop	Isoproturon + diflufenican improved protein and P% % in grain and flag leaves.
Brar & Walia (2008)	Wheat	Clodinafop (60 g ha^{-1}), Sulfosulfuron (25 g ha^{-1}), Mesosulfuron + Iodosulfuron (14.4 g ha^{-1})	*Phalaris minor*	Significantly reduced dry matter and nutrient uptake by weeds	All post-emergence herbicides were effective compared to the unweeded control.
Chopra *et al.* (2008)	Wheat	Fenoxaprop-p-ethyl + Carfentrazone-ethyl, 2,4-D, Metsulfuron-methyl	Mixed weeds	N & P depletion reduced by 54–87% and 44–83% over the weedy check	Fenoxaprop + Carfentrazone gave the highest N & P uptake by crop and best seed quality.
Dodamani & Das (2009)	Barley	Weed competition levels (0–128 plants m^{-2})	*Chenopodium album*, *Phalaris minor*, *Avena ludoviciana*, *Lolium temulentum*	Yield reduced by 31–36%	Increased weed density drastically lowered yield and nutrient uptake.
Tuti & Das (2011)	Barley	Weedy check	Mixed weed flora	Weeds removed 25.5 kg N, 12.0 kg P, 20.9 kg K ha^{-1}	High nutrient removal due to large weed biomass under no control.
Puniya *et al.* (2015)	Barley (Jobner)	Two hand weedings; Carfentrazone-ethyl	Mixed weeds	Two-hand weedings: highest agronomic	Carfentrazone treatment also

		(15 g ha^{-1} @ 30–35 DAS) + 30 kg N ha^{-1}		efficiency (AE = 16.2 kg grain/kg N) & N recovery (69.1%)	improved physiological N use efficiency.
Kumar *et al.* (2017)	Barley	Hand weeding twice, Fenoxaprop fb Metsulfuron, Isoproturon + 2,4-D, Weedy check	Mixed flora	Minimum N & P removal by weeds under hand weeding twice; maximum under weedy check	The interaction between residue and weed management significantly affected N & P removal.

Effect of Weed Management Practices on Growth of Barley

In addition to depriving crops of their basic growth requirements like nutrients, space, light, and moisture, weeds also inhibit germination and growth in general, causing massive losses to production of between 10 and 50 percent in wheat and barley (Walia *et al*., 1990). It has been proven by a number of studies that proper management of weeds is a key aspect that can enhance crop production and growth. Singh and Pandey (2006) indicated that the use of sulfosulfuron (33.3 g ha^{-1}) and metribuzin (250 g ha^{-1}) was successful in controlling large weeds like *Phalaris minor* and *Chenopodium album* in barley. Though carfentrazone-ethyl can have some temporary effects on the leaf specking or damage, plants exposed to the herb usually adapt after 2-3 weeks and do not suffer any loss of yield (Howalt, 2005). It was discovered by Singh *et al.* (2008) that the interaction between carfentrazone-ethyl and 2, 4-D had antagonistic effects on certain broadleaf weeds but was effective when interacted with tribenuron. Singh *et al.* (2011) discovered that the use of sulfosulfuron at a rate of 35 g ha^{-1} had a significant effect on reducing the total weed count and the dry matter of the weed in comparison to lower doses (20-25 g ha^{-1}) and the weedy check, suggesting a strong dose-dependent effect. Likewise, Bhullar *et al*. (2013) have found that carfentrazone-ethyl at 15, 20, or 25 g a.i. ha^{-1} was equal to metsulfuron-methyl in terms of its ability to control barley populations of broadleaf weeds (*Rumex dentatus*) by significantly reducing the numbers of *Rumex dentatus* (less than 3 plants m^{-1}) compared to 2,4-D sodium salt. The highest height of the barley plants was registered with carfentrazone-ethyl 50g ha^{-1}, then metsulfuron-methyl 20g ha^{-1}, and the lowest height was reported where there was the presence of weeds. Bhullar *et al*. (2013) also observed that all the rates of metsulfuron-methyl were effective in reducing both the weed density and biomass in three growing seasons. Shridevi *et al*. (2013) emphasized that heavy infestation of weeds reduced the height of plants, caused high levels of mortality due to increased tillers, and decrease in shoot and grain yield. Singh *et al*. (2013) also discovered that carfentrazone-ethyl @ 20 g ha^{-1} had a positive response with a significant increase in plant height and effective tillers with the increase in dose levels. Post-emergence contact herbicide carfentrazone-ethyl is desiccating in action, immobile in soil, lacks residual activity (half-life of 25 days), and the weed is rainfast in a few hours. It is also compatible with a number of herbicides and works best when used at the early stages of weed growth (Chopra and Chopra, 2005; Willis *et al*., 2007; Singh, 2009; Yadav *et al*., 2009; Singh *et al*., 2010). Bhaduri and Gautam (2013) have found that grain yield has a considerable positive association with the plant growth parameters, including the plant height, the dry matter accumulation, the number of spikes per spike, the weight of the spike, the length of the spike, the number of grains per spike, and the biological yield. In the same manner, the two hand weedings (25 and 50 DAS) in Puniya *et al.* (2015) gave the highest growth, yield attributes, and productivity of barley, then the metsulfuron-methyl (4.0 g ha^{-1} at 30-35 DAS). Two-hand weedings resulted in the highest net returns with yield benefits of 7.0, 12.2, and 15.5 over metsulfuron-methyl, one-hand weeding, and 2,4-D ester (0.5 kg ha^{-1}), respectively. Besides, metsulfuron-methyl with 90 kg N ha^{-1} had the best benefit-cost ratio (4.37), then 2,4-D ester (4.09). Bhagat Singh *et al*. (2017) also found that the levels of control of the weed reduced greatly, both the grassy and broadleaf weeds, at 60 and 90 DAS. The greatest amount of the effective tillers was recorded in the weed-free treatment that was statistically equal to pinoxaden + carfentrazone (40 + 20 g ha^{-1}), pinoxaden + metsulfuron (40 + 4 g ha^{-1}), and isoproturon + 2,4-D (750 + 500 g ha^{-1}). The weedy check, on the other hand, had the least number of productive tillers because of increased weed density and biomass.

Effect of Weed Management Practices on Yield and Yield Attributes of Barley

Competition among weeds has a significant impact on the yield and quality of barley and other cereals, as it reduces nutrient availability, light absorption, and moisture use. The extent of yield loss because of weed infestation can be wide-ranging based on the density of the crops, the weed flora, and the management. Doll (1997) examined the effect of crop plant density and cultivar on the growth of barley in spring at normal, half, and quarter distributions over 1993-94 and found that weeds had a 2 to 5 fold greater amount of dry matter after two seasons of spring barley where the number of plants was reduced to half and quarter the normal level. The increase in the grain yield caused by the herbicide treatment was 13, 24, and 34 percent at normal, half, and quarter barley densities, respectively. This research found that the optimum population of barley plants was more significant to the competitiveness of the weed than to the highest yield, with a negative relationship between the individual grain yield and the growth of the weeds being significant. Dhima *et al.* (2000) also found that barley cultivars with low competitive ability against *Avena sterilis* and *Phalaris minor* yield less biomass and grain. Their four-year experiment (1994-1997) revealed that the abundance of 120 m^2 plants of *A. sterilis* resulted in the reduction of yield by between 8 and 67 percent relative to the control (no-weed) plots. On the same note, Gill and Brar (1975) have found that infestation of *Phalaris minor* led to 15-20% yield reduction in wheat. Research done by Torner *et al.* (1984) showed that barley had a yield reduction of 20-80% in competition with *Avena fatua* and *Phalaris* spp. Based on weed density, time of emergence, and cultivar. According to Tomar and Vivek (2003), the highest number of effective tillers and grain yield were recorded in weed-free plots, then sulfosulfuron, clodinafop, and fenoxaprop-p-ethyl treatments. Al-Johani *et al.* (2012) established that *Chenopodium murale* was more harmful to the barley growth parameter in comparison with *Malva parviflora*. Shoeran *et al.* (2013) observed 37.2% and 33.1% grain yield loss as a result of continuous infestation with weeds between 2006 and 2007 and the second between 2007 and 2008, respectively, relative to the weed-free control. An evaluation of herbicides with various modes of action, one of which is carfentrazone-ethyl, was conducted on CCS Haryana Agricultural University, Hisar, and recorded carfentrazone-ethyl as being significantly better than metsulfuron and 2,4-D ester in the context of broadleaf weed control, where efficiency of up to 85 percent weed control was recorded (Singh *et al.*, 2007). Carfentrazone was more effective on Convolvulus arvensis, *Rumex dentatus*, and *Malva parviflora*, but less effective on *Chenopodium album* and *Melilotus indica*. Paswan *et al.* (2012) found that the combinations of 50 g ha^{-1} + 0.2 percent surfactant resulted in the highest increase in yield qualities and grain yield, then the combinations of 25 g ha^{-1} + surfactant and 30 g ha^{-1} + surfactant. Equally, Malik *et al.* (2013) also found that clodinafop-propargyl + metsulfuron-methyl (60 + 4 g ha^{-1}) had the highest number of spikes, 1000-grain weight, and grain yield in wheat, similar to the control without weeds.

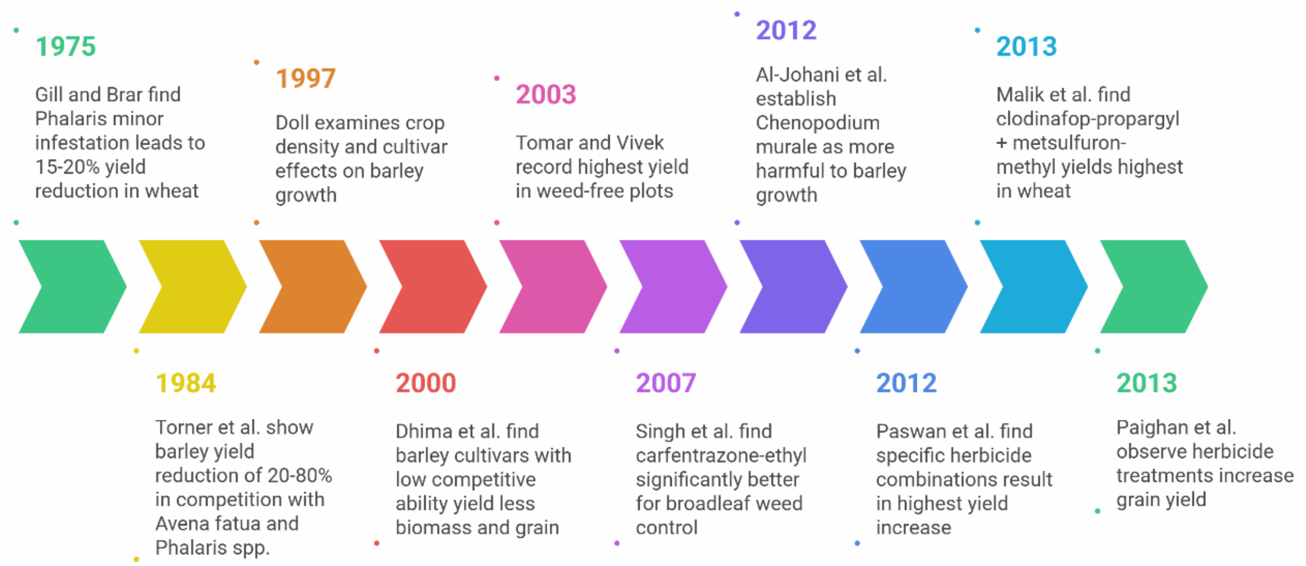

Fig. 2: Key Milestones in Barley Weed Management Research

Paighan *et al.* (2013) observed that herbicide treatments both significantly increased grain yield over the weedy check, and the weed-free plots, and metsulfuron-methyl (4 g ha^{-1}) yielded the highest grain and straw yields. According to Jain *et al.* (2014), the use of clodinafop, then 2,4-D, had a higher grain yield of 4.9, 6.5, and 18% than isoproturon, clodinafop, and the weedy check, respectively. The authors showed that vegetable and mineral oil adjuvants (1%) helped in improving the activity of herbicides, decreasing the dry weight of weeds, and boosting the grain yield and its components in barley (Shaban *et al*., 2015). Sirazuddin *et al*. (2017) compared the performance of different weed management practices and a variety of establishment methods and found that the clodinafop-propargyl at 60 g ha^{-1} had the greatest decrease in weed dry matter and the highest harvest index, which was statistically equal to that of zero tillage wheat (ZTW). In addition, the maximum number of grains per spike was also achieved in the ready mix of clodinafop-propargyl + metsulfuron-methyl @ 64 g ha^{-1}. All in all, these studies show that weed management, where selective herbicides are used or a combination of mechanical and chemical methods is used to control weeds, not only inhibits weed growth but also positively influences yield characteristics like height of the plants, number of spikes, grains per spike, and 1000-grain weight, which results in improved productivity and profitability of barley farming.

Effect of weed management practices on returns

A decrease in the amount of herbicides used in agriculture has become a major issue in recent years, and integrated weed management systems that bring together economic and environmental sustainability are in the spotlight. The identification of the economic threshold of the weeds, which is the density that results in the cost of the control mechanism matching the benefit obtained, is one of the main principles within such systems (Cussans *et al*., 1986). The consequence of organic management is that it tends to increase the diversity and density of the weed, causing a reduction in the net farm income through the lowering of the yield (Pardo *et al*., 2008; Swezey *et al*., 2007). As much as it is believed that increased biodiversity can have ecological advantages, the direct changes of biodiversity on the management, yield, and profitability of weeds are hard to quantify (Gomiero *et al*., 2011). In others, the yield of organic systems has decreased by as much as 50 percent than the conventional systems due to poor weed control (Hawes *et al*., 2010). Such losses can, however, be compensated using integrated and innovative methods, which sustain yield and farm income. According to Bhullar *et al*. (2013), a similar effect was found with lower rates of carfentrazone-ethyl and metsulfuron-methyl, which were just as effective as higher rates in improving the barley yield, with similar results to using 2,4-D to suppress broadleaf weeds and minimize competition between crops and weeds. Likewise, Prameela *et al*. (2014) have discovered that the greatest returns were obtained with the use of sulfosulfuron sprayed and clodinofob (Rs. 67,090) with a benefit-cost ratio (B: C) of 1.8. Negi *et al*. (2015) noted that the combination of isoproturon + metsulfuron (1.00 + 0.004 kg/ha) and two hand-weedings enhanced the barley grain yield by 8.727.3 percent as compared to the other herbicides, and maximum net returns (Rs. 4,661/ha) were attained with a B: C ratio of 2.32. Puniya *et al*. (2015) also stated that the two hand-weedings at 25 and 50 days after sowing had the highest productivity and profitability, followed closely by metsulfuron-methyl at 4 g/ha. Metsulfuron-methyl combined with 90 kg N/ha gave the best B: C ratio (4.37), followed by 2,4-D ester (4.09), thereby indicating that integrated weed and nutrient management techniques significantly increase yield and economic returns in barley production.

Nutrient Management:

Effect of organic manures on weed flora

The problem of weed infestation has been one of the significant problems in modern agriculture, and the weed seeds are spread in different ways, such as seeds of contaminated crops, farmyard manure, irrigation water, factory machinery, livestock, birds, and wind (Dastgheib, 1989). The relationship between weed flora and the use of organic manure has been pointed out in several studies as a complex factor. According to Badiyala *et al*. (1991), the use of farmyard manure (FYM) alone or with biofertilizers had a significant positive effect on the weed density and dry matter accretion. Chouby *et al*. (1998) also determined that the use of FYM when considering chemical fertilizing in rice would lead to an increased total population of weeds as compared to the use of chemical fertilizers alone. Girish and Chandrashekar (2000) carried out a survey in Karnataka to find out that most farmers did not use FYM due to high weed infestations related to its usage. Through the use of vermicompost, Singh *et al*. (2004) noted that the biomass of the weed was promoted, possibly because of the enhanced and sustained nutrient availability to both crops and weeds. As Khokhar and Nepalia (2010) reported, the nutrient management did not cause any change in the weed density but instead, the biomass of the weed grew substantially with the application of 75 percent of RDF + vermicompost (1.5 t ha^{-1}) and 50 percent RDF + vermicompost (3.0 t ha^{-1}), and maximum biomass of weed was 230.44 kg ha $^{-1}$ when 50 percent of the same was applied. The authors of Sharma *et al*. (2015) researched the efficacy of various herbicides in wheat and identified clodinafop + metsulfuron (60 + 4 g ha^{-1}) and isoproturon + 2, 4-D (1.0 + 0.5 kg ha^{-1}) as effective to manage *Phalaris minor* (48% of total weed flora).

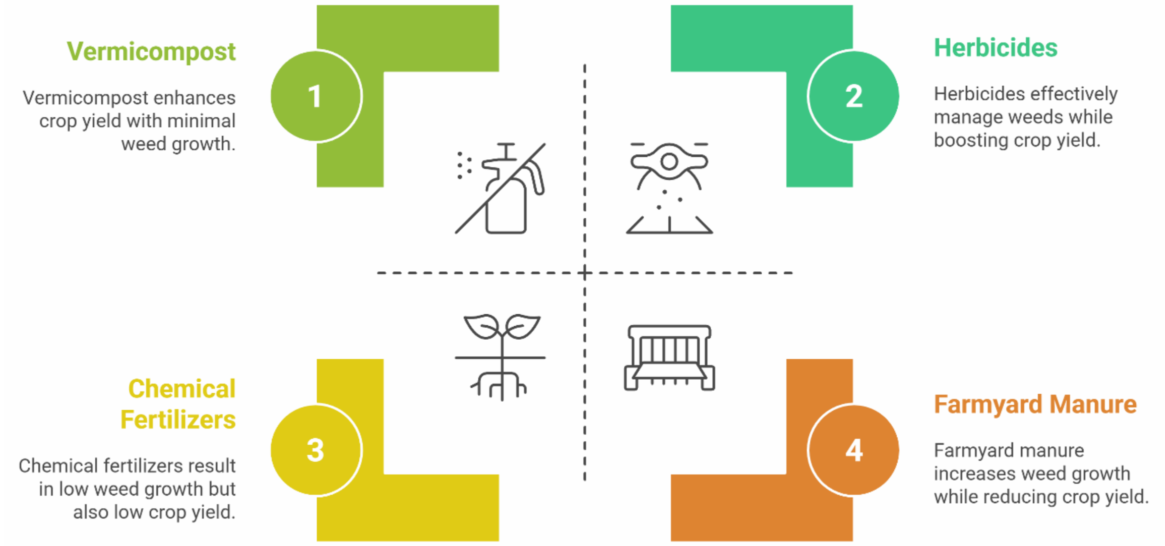

Fig. 3: Impact of Organic Manures and Herbicides on Weed Growth

The results indicate that although FYM and organic amendments enhance the physical, chemical, and biological makeup of soil and have long-term effects on future crops, they are likely to enhance weed growth unless effectively controlled. Pal *et al.* (2016) also showed that herbicidal application of mesosulfuron + iodosulfuron (24 + 4.8 g ha^{-1}) and sulfosulfuron + metsulfuron (20 + 4 g ha^{-1}) in wheat was effective in reducing the weed density, and nutrient removal by the weed but significantly enhancing the height of the plant, the number of tillers, the yield of grain (5.23 t ha^{-1}) and uptake of nutrients, and was as effective.

Effect of organic manures on barley

According to Landan (1991), most crops, such as barley, have an optimal pH of between 6.5 and 7.5 in where they grow best and where the availability of nitrogen is the highest. The use of 100% farmyard manure (FYM) was found to greatly increase organic carbon in the soil (2.987) and organic matter (5.14%), which shows that the soil is healthier. The combination 25:75% NPS: FYM yielded the greatest overall nitrogen levels (0.385%), with the soil nitrogen levels falling within low and medium (0.129 to 0.385%). Olson *et al.* (2010) noted that the highest percentage of successful nitrogen recovery was recorded with annual N + P (45) and N alone (41) of synthetic fertilizer, phosphorus-organic amendments (2634), annual nitrogen manure (15), and nitrogen compost (10). On the same note, the recovery of phosphorus was maximum with synthetic fertilizer N + P (30%), minimum with nitrogen-containing manure (6%), and compost (4%). They concluded that application of phosphorus-based manure or compost is capable of sustaining good crop production but cannot accumulate in the soil. Sekhawat and Sekhawat (2010) also indicated that FYM use caused a significant increase in the availability of nitrogen, phosphorus, and potassium in the soil relative to the control, whereas the application of inorganic fertilizer with a ratio of 120 kg N + 60 kg P_2O_5 ha^{-1} also led to an increase in phosphorus status in the soil. Organic manures enhance the physical, biological, and chemical characteristics of soil, enhance the retention capacity of nutrients, and diminish toxicity. They enhance microbial activity as a source of food and energy, the transformation of unavailable nutrients into available ones, which leads to enhancement of crop growth, yield, and quality (Yawalkar *et al.*, 1992). Dinka *et al.* (2018) proved that the use of FYM with NPS fertilizer has a big impact on the growth and yield characteristics of barley. The treatment condition (12 t FYM ha^{-1} NPS: FYM 33.4:66.6) gave the maximum number of effective tillers (270 m^{-2} and 13 rent plants), whereas 75:25% NPS: FYM showed the greatest height of the plant (90 cm). The highest panicle length and the heaviest panicle and kernel weight were obtained with a proportion of NPS: FYM at a 50:50% ratio. The maximum grain yield (6,496 kg ha^{-1}) and biomass yield (15,917 kg ha^{-1}) were obtained at 66.6:33.4% NPS: FYM, which also proved to be both economically viable in the production of barley in the Toke Kutaye District and other comparable agro-ecological areas.

Effect on soil properties

According to Dhaliwal and Walia (2008), the incorporation of farmyard manure (FYM), green manure (GM), and incorporation of crop residues (CRI) into the soil has a great ability to enhance soil health through improving its physico-chemical characteristics. Not only do these organic amendments provide the necessary macronutrients, i.e., nitrogen (N), phosphorus (P), and potassium (K), but they also enhance the supply of vital micronutrients like zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). Their usage was also observed to lower soil bulk density and augment soil organic carbon, field capacity, permanent wilting point, and accessible soil moisture. Using the proportion of particle sizes, FAO (2008) revealed fine particles dominated the soils of particle size distribution of 4.1% sand, 15% silt, and 80.9% clay, which affected the dynamics of nutrients. The pH of soil was found to be greater (5.84) in plots with application of 100 percent NPS fertilizer, whereas the pH of plots with 100 percent application of FYM fell in a range of 4.75 to 4.99. In the last century, the scientific knowledge of the nutrition of plants and soil fertility has made significant progress. First, the fertilizers were primarily composed of inorganic nutrients as they were cheap and readily obtained. Nevertheless, the use of chemical fertilizers has not been sustainable, since they do not provide micronutrients needed to have a balanced growth of plants (Hesse, 1984). Organic manures also contribute positively in regaining soil fertility through raising the level of content of organic matter that contributes to the water-absorbing properties in sandy soils and water-draining properties in clay soils (Gupta *et al.*, 1990). Verma *et al.* (2010) discovered that the application of 20 t FYM ha^{-1} or the combination of NPK with 10 t FYM ha^{-1} had a significant positive effect on soil properties. Bandyopadhyay *et al.* (2010) also found that integrated NPK+ FYM management had a better effect on soil organic carbon and bulk density (5.6 and 9.3, respectively) than NPK and control. Thakur *et al.* (2011) also noted that the recommended dose of NPK (20:80:20 kg ha^{-1}) used in soybean with the 15 t FYM ha^{-1} increased soil organic carbon and nutrient availability (N, P, K, and S). Aher *et al.* (2015) compared the soil organic carbon, available nitrogen, and phosphorus (11.3 g kg^{-1}, 125 mg kg^{-1}, and 49.7 mg kg^{-1}, respectively) under organic and chemical management systems in soybean, showing a significant increase, and potassium levels were not different. According to Brabet *et al.* (2015), soil organic matter, soil structure, and crop yield were enhanced by the use of organic and inorganic fertilizers on wheat in the long term. Application of balanced NPK + FYM improved the carbon sequestration of the soil and stability of its yield. Dubey *et al.* (2015) have also noted that 100 percent NPK mixed with FYM made a significant contribution to improving the soil physico-chemical character and uptake of nutrients in wheat. Sharma *et al.* (2015) established that soil pH was relatively constant with the long-term integrated application of fertilizers as 10 t FYM ha^{-1}, whereas the control plots had the least organic carbon (5.1 g kg^{-1}). The application of FYM on an ongoing basis at the rate of 20 t ha, inherent to the soils, enhanced the electrical conductivity and fertility of the soil. Mairan *et al.* (2016) showed that combining organic and inorganic sources of nutrients in the cropping systems, including soybean-pigeon pea and sorghum-pigeon pea, improved the soil properties. Treatments 50% recommended fertilizer dose (RDF) + FYM 2.5 t ha^{-1} and other organics such as vermicompost, press mud cake, neem seed cake, and biofertilizers decreased soil bulk density and pH and increased the porosity, rate of infiltration, moisture content, and organic carbon. These results have proved that organic amendments are crucial towards enhancing physico-chemical and biological characteristics of soils that help in the management of soil fertility sustainably.

Effect on growth

Fertilizers are very important in the growth and increase in the production of crops; at the same time, the constant and unbalanced application of high-analysis chemical fertilizers may have negative impacts on the potential capacity and soil health. In order to achieve long-term productivity, chemical fertilizers should be used in conjunction with organic manures, including farmyard manure (FYM), to enhance the soil fertility and structure (Bajpai *et al.*, 2006). FYM is a crucial source of nutrients, which has a direct impact on the soil characteristics and plant development. According to Sharma (1981), FYM at 12 t ha^{-1} and NPK at their application greatly increased the panicle length, the number of panicles per square meter, grains per panicle, and the weight of test in barley in comparison to the application of fertilizer alone, bridging N at 12 t ha^{-1}. Agarwal *et al.* (2003) concluded that 75 percent vermicompost and 25 percent FYM had the highest relative plant height, number of leaves, plant dry weight, number of seeds per spike, test weight, grain yield, and harvest index at 105 DAS. On the same note, Yadav *et al.* (2005) found out that the 180kg N ha^{-1} over 120kg N ha^{-1} increased the number of effective tillers per row by 29.3 and Ram and Mir (2006) found that FYM at 10 t ha^{-1} + 120kg N ha^{-1} significantly increased plant height and tiller length in comparison with low levels of nitrogen or control. FYM application by Singh *et al.* (2007) also enhanced the growth parameters of wheat and barley growth, like plant height, tiller density, spike length, grain weight per spike, and the total yield. Moreover, Singh *et al.* (2008) established that 7.5 t ha^{-1} FYM coupled with 50 percent RDF and biofertilizers led to the maximum height of the plants and tills. Sepat *et al.*

(2010) established that incorporation of FYM and biofertilizers with fertilizer combinants had significant effects in enhancing the number of spikes per square meter, grains per spike, and the amount of test weight, and Singh and Pal (2011) established that the tallest plants and the highest accumulation of dry matter were achieved through incorporation of FYM and biofertilizers with fertilizer combinants, which performed equally with 75% RDF + FYM + Azotobacter. Overall, the studies indicate that through the application of FYM, biofertilizers, and balanced fertilizers, there is growth, yield, and an increase in the overall soil health in cereals such as barley and wheat.

Effect on yield and yield attributes

Through the studies, Patel and Upadhyay (1993) established that the use of farmyard manure (FYM) positively affected root growth, tillering, and flowering, resulting in higher yield and grain quality in barley. They found out that FYM at 15 t ha^{-1} improved grain protein content between 0 and 150 t ha^{-1}, which served as a nutrient reservoir of crucial elements such as N, P, K, and micronutrients. In the same manner, Kumawat and Agarwal (1999) established that the nitrogen level yielded a maximum of 58 kg N ha^{-1}, but statistically the same as 60 kg N ha^{-1}. Effective tillers, grains per spike, and 1000-grain weight improved with the increase of the amount of nitrogen applied to the barley until 75 kg N ha^{-1}. The seed and straw yield were utmost at 75 kg N ha^{-1} when there was no FYM, but only to 60 kg N ha^{-1} when FYM was used, showing that it carries with it the nutrient content it provides. It was also found that FYM at the rate of 10 t ha^{-1} resulted in greater ear length, grains per ear, 1000-grain weight, and grain and straw yields, which are beneficial in improving soil fertility (Singh *et al.*, 1999). A combination of NPK and FYM (10 t/ha) increased the yield of wheat by 138.5 (grain) and 123 percent (straw) compared to the control, indicating the effect of FYM on soil nutrients. Woldesenbet and Tana (2014) discovered that 100% NPS and FYM or 50:50 NPS: FYM combination yielded significantly more kernels per plant than when plots were unfertilized, with 5 t FYM ha^{-1} + 75% inorganic NP yielding the highest number of grains per spike. According to Ram *et al.* (2014), integrated nutrient management (66.6:33.4% NPS: FYM) enhanced the yield of barley grain (6496 kg ha^{-1}) significantly as compared to that of 100% NPS (6288 kg ha^{-1}). On the same note, Sant Bahadur Singh (2017) found that the highest values were observed with 100% NPK + 5 t FYM ha^{-1} + biofertilizer, leading to higher yields of 49.9 q ha^{-1} grain and 87.4 q ha^{-1} straw as compared to 24.9 and 53.9 q ha^{-1} with 100% NPK. It also gave the highest protein production (543.9 kg ha^{-1}) under this combined treatment, underpinning the synergistic nature of using FYM, biofertilizers, and chemical fertilizers in the production of barley.

Effect on nutrient content uptake and quality

The use of FYM at 15 t ha^{-1} was found by Patel and Upadhyay (1993) to improve the protein content of the grain more than when no FYM was used, which supports the importance of using FYM to improve the quality of crops. On a similar note, Bendi and Biswas (1997) have also indicated that there was no zinc deficiency in the FYM-enhanced plots, and the crop yields were also higher, and the uptake of the nutrients (N, P, and K) was also significantly higher than the unmanured plots, which were further improved by application of graded nutrients. Prasad and Prasad (1998) noted that a vast fraction of nutrients of organic origin were made available to the wheat, and the leftover effects were felt on the subsequent crops of the cropping system. It is indicated that with the application of FYM, vermicompost, green manuring, and rice residue, either as a single one or in combination with biofertilizers and NPK fertilizers, the soil fertility could be enhanced and the constant productivity of such soils could be sustained (Singh *et al.* 2008). Verma and Mathur (2009) also established that the active pools of soil carbon were strongly influenced by the integrated or sole use of FYM, with the C/N ratio exhibiting good correlations with the microbial biomass carbon and nitrogen, water-soluble carbon, carbohydrates, and dehydrogenase activity in maize soils. Verma *et al.* (2010) observed huge changes in soil physicochemical properties when using FYM alone or mixed with inorganic fertilizers that included decreased bulk density, enhancements in electrical conductivity (EC), and cation exchange capacity (CEC) that was not accompanied by changes in soil pH. These gains were explained by the increased plant residues, application by increased root and stubble development in FYM plots. In terms of effects of 75 percent NPK + 5 t FYM ha^{-1}, Sant Bahadur Singh (2017) reported that maximum grain protein (11.1 percent) and straw protein (3.4 percent) was observed at less than 100 percent NPK, and that combined use of 75 percent NPK along with 5 t FYM ha^{-1} had a significant positive effect on grain starch content (54 percent) and improved N, P, and K absorption by both grain and straw, which is the synergistic effect of using.

Effect of inorganic fertilizers on barley

The important contribution of fertilizers to crop production is not a recent development, and their use is now de facto to attain high yields in contemporary wheat production. Nevertheless, although chemical fertilizers have enormously enhanced crop yield, their overuse and imbalance have caused a number of environmental challenges, such as soil degradation, air and water pollution, and health risks to humans, and thus, jeopardizing sustainability in agriculture in the long term (Eid *et al*., 2006). To enhance crop productivity, fertilizers are necessary, and the continuous use of high-analysis chemical fertilizers has a detrimental impact on soil fertility and its potential production. As such, chemical fertilizers need to be combined with organic manure to keep the soil healthy and to assure sustainability in yield (Bajpai *et al*., 2006). According to Behara (1995), the application of the optimum amount of fertilizers and the right application methods would achieve maximum productivity and profitability, whereas Behara *et al*. (2007) pointed out the significance of a balanced amount of nutrients and the right sources of nutrients in enhancing crop yields. The long-term cultivation using inorganic fertilizers has brought about the falling soil productivity, implying the necessity of using the inorganic sources alongside the organic manures and micronutrients to maintain the soil fertility and productivity. According to Dejene *et al*. (2014), when nitrogen and phosphorus fertilization rates were used in combination with additional irrigation, barley reacted significantly. The authors conducted a study where the nitrogen (N) and phosphorus (P) fertilizer was applied to the Sasa barley variety in a split-split plot design to determine the optimum yield under different sites with different N and P regimes, which showed that the optimum yield varied between sites with different N and P regimes. Such results indicate that site-specific nutrient management guidelines are required instead of a blanket 100 kg ha^{-1} urea and DAP, 20 kg ha^{-1} nitrogen and phosphorus to manage barley yields and sustain soils under different growing conditions.

Effect on growth

Mahajan *et al*. (1993) noted that 60 kg N ha^{-1} gave maximum root depth, primary roots per plant, and root weight per plant in barley as opposed to low nitrogen concentrations (40, 20, and 0 kg N ha^{-1}). On the same note, Sood *et al*. (1993) found that 60 kg N ha^{-1} performed significantly in height of the plants, the number of plants per meter row length, and dry matter production. Faithi *et al*. (1997) observed that the optimal rate of nitrogen used in producing dry matter at the stage of spike emergence was 80 kg N ha^{-1}, where the nitrogen was used much more effectively in growth, especially in height increase. Thakur *et al*. (2004) discovered that the higher the level of nitrogen and phosphorus to 120kg N + 60kg P_2O_5 ha^{-1}, the higher were total tillers, whereas plant height only reached 60kg N + 40kg P_2O_5 ha^{-1}. Kumawat and Jat (2005) established the greatest number of active tillers every meter row length at 60 kg N ha^{-1}, which was greatly better than 40 and 20 kg N ha^{-1} at Jobner, Rajasthan. Narolia (2009) of Bikaner discovered that 90 kg/ha N^{-1} was significantly better in increasing plant height, stem and leaf weight/meter row length, dry matter accretion, and total tillers at every growth stage than lesser levels of N and the control. Both Paramjit Singh *et al*. (2002) and Singh *et al*. (2013) stated that the increase of nitrogen to 90–120 kg ha^{-1} in barley and wheat, respectively, had a significant positive effect on the growth parameters, such as plant height and dry matter accumulation, whereas Jat *et al*. (2013) applied the same range of nitrogen at Udaipur in wheat. According to Kumar (2004), growth in plant height, number of tillers per plant, and accumulation of dry matter in barley increased tremendously under application of nitrogen in amounts up to 90 kg N ha^{-1}. The study conducted by Roy *et al*. (2004) revealed that 10 t ha^{-1} vermicompost was effective in enhancing the growth characteristics of the plants (plant height, number of tiliers, and accumulation of dry mass) relative to the control. Shekhawat and Shekhawat (2010) also stated that the application of 120 kg N + 60 kg P_2O_5 ha^{-1} increased barley yield and yield factors, but Yadav *et al*. (2005) found a significant effect of nitrogen rates on the barley plant height and effective tillers; 29.3% at 100 kg N ha^{-1} and 29.3% at 120 kg N ha^{-1} respectively. Ram *et al*. (2014) noticed that the integrated nutrient management had a great effect on the leaf area index (LAI) of barley, where the highest LAI (0.484) was observed when it was used as a 50:50 percentage of NPS: FYM application was observed in comparison with the lowest LAI (0.303) when no application was done. In the same way, Mitiku *et al*. (2014) established that the combination of 5 t ha^{-1} farmyard manure or vermicompost and 75% recommended NP fertilizers produced a significant improvement in plant height at Adiyo and Ghimbo, and Woubshet *et al*. (2017) found the maximum barley plant height in the integrated use of lime, balanced fertilizers, and compost in Wolmera district.

Effect on yield and yield attributes

Gwal *et al* (1999) carried out a field experiment in a field named Sehore, Madhya Pradesh, to determine the impact of various levels of fertilizers on late-sown wheat and discovered that spike length and grain protein content rose with an increase in the NPK rates. Likewise, at Kanpur, Katiyar and Uttam (2007) found that the application of 60 kg N + 30 kg P_2O_5 + 40 kg

K_2O ha^{-1} had a great effect on yield attributes and yield of barley, in comparison to 40 kg N + 20 kg P_2O_5 + 20 kg K_2O ha^{-1}. In salt-tolerant wheat in sodic soils amended with gypsum, Singh *et al*. (2008) observed that the response to a rise in nitrogen levels appeared positive in the range of 70 to 120 kg N ha^{-1}. Moreover, added to the recommended dose of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1}, Singh *et al*. (2009) in Faizabad discovered that supply of an extra portion of 40 kg of N ha^{-1} on top of recommended dose at 45 DAS dramatically enhanced green fodder, grain, and straw yield of barley by 17.2, 15.4, 11.7 and 40.9 percent, respectively, as compared to the yield Verma (2010) noted that the test weight, spike number, husk content, and grain yield of the malt barley were significantly improved with increasing levels of nitrogen up to 90 kg ha^{-1} in relation to 60 kg ha^{-1}. Bikaner reported 120 kg N + 60 kg P_2O_5 ha^{-1} to increase barley grain yield by 9.5, 33.6, 54.3, and 186.8 over lower levels of N and P_2O_5 and control, respectively, and their higher level of straw yield also increased up to 95.5 (Shaktawat and Shekhawat 2010). Meena *et al*. (2012) also established that 90 kg N ha $^{-1}$ led to an increase in barley grain, fodder, and total dry matter yield by 5.8, 0.95, and 0.93 t ha^{-1}, respectively, compared to an increase in 30 kg N ha^{-1}. Bhaduri and Gautam (2012) noted the highest grain and straw yield of 46.6 and 67.6 q ha^{-1}, respectively, at 200 kg N/ha, and a good response at 150 kg N/ha, respectively, as a result of enhanced vegetative growth. Mohanty *et al*. (2015) have found that the nutrient management technique using soil test crop response (STCR), improved the yields significantly, where the application of 10 kg N, 95 kg P_2O_5, and 10 kg K_2O ha^{-1} depending on the soil fertility and yield goals increased the root biomass, effective tillers, grains per ear, and test weight, leading to high grain and straw yield as a consequence of improved phosphorus availability. Kassa and Sorsa (2015) found that NP 69/30 kg ha^{-1} had significant effects ($P < 0.05$) of nitrogen and phosphorus on plant height, spike length, seeds per spike, and grain yield, with the highest yield (2.02 t ha^{-1}) and lowest (0.86 t ha^{-1}) of 0/0 NP. Likewise, Ketema Niguse and Mulatu Kassaye (2018) discovered that the highest yield (4.51 t ha^{-1}) was obtained with barley variety EH 1493 with 69 kg N ha^{-1}, then statistically equivalent, with 46 kg N ha^{-1}, and the lowest yield (1.42 t ha^{-1}) was realized with HB1307 when no nitrogen was applied.

Effect on nutrient content, uptake, and quality

According to Birch and Long (1990), the grain protein content of barley had been found to follow quadratic equations, with the lowest protein levels being found in the range of 9-55 kg N/ha, and the protein content was found to increase with nitrogen rate, linearly in Corvette and quadratically in other barley varieties. According to Sood *et al*. (1993), the content of crude protein and yield of barley substantially improved when 60 kg N/ha of nitrogen was used as compared to the low nitrogen levels. In the same way, Singh and Singh (1991) noted that the content of crude protein increased significantly to 90 kg N/ha. According to Pandey *et al*. (2000), an increase in the level of fertilizers led to an increase in crop performance, uptake of nutrients, and weed biomass when compared to the no-fertilizer status. The results indicated that the N, P, and K uptake in barley grain and straw was enhanced by nitrogen fertilization of 40, 80, and 120 kg/ha, with maximum nutrient concentration at 120 kg N/ha (Gupta *et al*., 2001). Kumawat (2009) also established that the 100 percent recommended nitrogen dose had a better effect in enhancing crude protein content than lower doses. According to Singh and Singh (2005), nitrogen level increased to 80kg/ha, increased N content of malt barley, whereas protein content increased to a large extent to 60kg N/ha. At Jobner, 60 kg N/ha enhanced total N, P, and K uptake by 8.9, 5.8, and 6.5 percent, respectively, compared to 40 kg N/ha. Katiyar and Uttam (2007) documented the fact that N + P_2O_5 + K_2O 30 kg/ha was the maximum concentration of nutrients and uptake. Singh *et al*. (2009) also discovered that raised N uptake by 20 kg N/ha and control by 50.6 and 21.4, respectively. Bhaduri and Gautam (2012) noted an increase in nutrient uptake, from 112.3 to 130.4 kg/ha, with N application of 150-200kg/ha, and 170:60:120 kg/ha resulted in the maximum nutrient uptake (Barthwal *et al*., 2013).

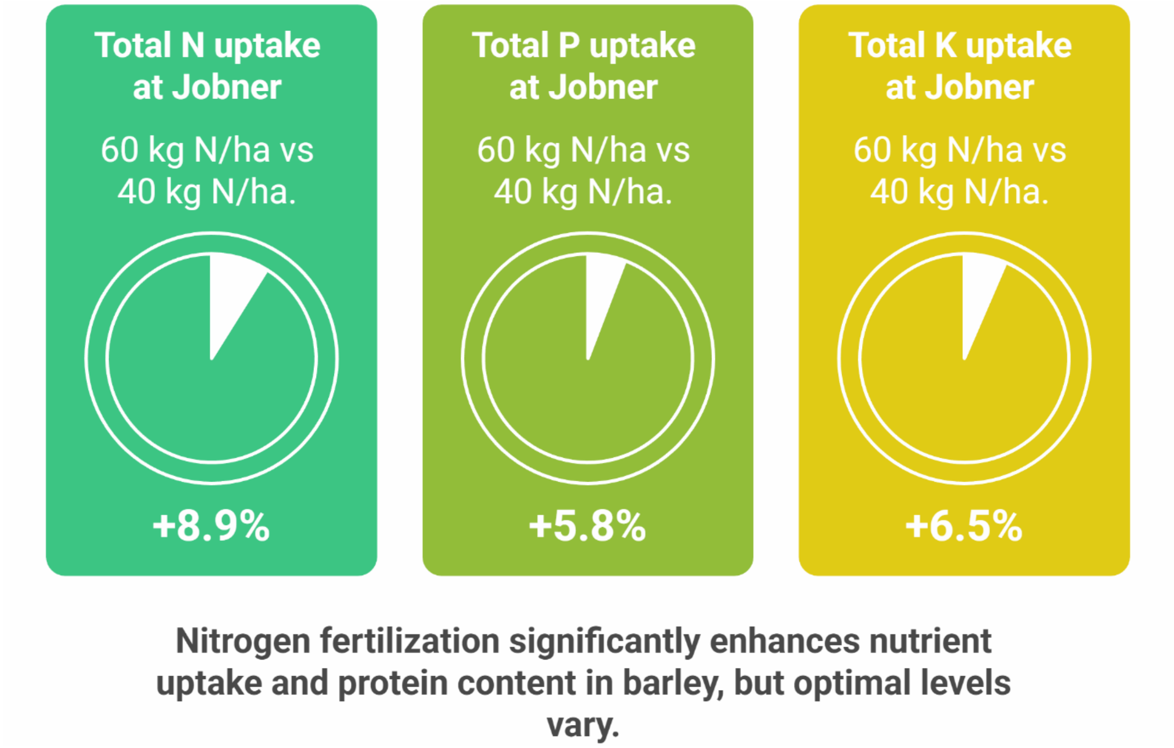

Fig. 4: Nitrogen's Impact on Barley Nutrient Uptake

Meena *et al*. (2012) have indicated that N content, uptake, protein, and yield were found to increase progressively with nitrogen between 30 and 90 kg/ha. Jat *et al*. (2013) discovered that 9 kg Zn/ha was highly effective in promoting N, P, K, S, and Zn uptake in wheat, whereas Hansram *et al*. (2017) also observed that the barley variety RD 2552 exhibited under PNMP4 and PNMP5 had a higher N, P, and K content and total uptake than other nutrient management techniques.

Effect on returns

Gupta *et al*. (2007) noted that there was an increase in net return and benefit-cost (B: C) ratio with the doses of fertilizers, with the highest returns having 125 percent of the recommended fertilizer dose over a span of two years. According to Katiyar and Uttam (2008), the highest net return was obtained with the application of 60 kg N + 30 kg P_2O_5 + 30 kg K_2O/ha, which was followed by 50:25:25 kg NPK/ha, 20:20:25 kg NPK/ha, and 30:15:15 kg NPK/ha. Kumpawat (2009) established that when the amount of nitrogen was raised to 100 percent of the recommended dose, the profitability was substantially improved with the highest net return (30,208/ha), B: C ratio (3.4), and sustainability yield index (0.83). Tyagi (2006) highlighted that the combination of organic sources with 50 percent NPK/ha lowered the cost of cultivation, besides improving the production of produce. The highest B: C ratio (1.517) was presented by Pandey *et al*. (2009) as 10 t FYM/ha alone, as added to recommended dose of fertilizers (RDF), whereas the Yadav *et al*. (2009) stated that economic viability is a major determinant of adoption in farmers, with total cultivation costs of 34250 to 37550/ha and Net return of highest value (57650/ha) was observed in case of in situ incorporation of W In NDUA&T, Faizabad, Singh *et al*. (2010) discovered that 100 percent RDF of NPK measured significantly more net returns as compared with lower doses and statistically equal to 75 percent RDF using fertilizers and 25 percent RDF using FYM. Upasani *et al*. (2013) found that the level of nitrogen of up to 120 kg/ha increased yield (grain: 2.90 t/ha; straw: 4.6 t/ha), net return (26,616 /ha), and B: C ratio (1.52). Woubshet *et al*. (2017) discovered that lime and compost combined with blended fertilizer (NPSB) had the greatest net return (EB 30,633) with the marginal rate of return of 667 into 1 with a value cost ratio of EB 5.49 per unit barley production. The most profitable combination (980%) was realised at a 50:50 blend of farmyard manure and compost or vermicompost mixed with NP fertilizer, which showed that it was profitable in Chelia highlands. Likewise, the best net benefit (EB 49,015.45/ha) and marginal rate of return (136) were found in the application of 36 kg N/ha and barley variety Ibon 174/03, which was agronomically and economically viable in the production of malt barley in Wolmera area (Terefe *et al.*, 2018).

Interaction with fertilizer and herbicide

The data about the effects of management strategies like herbicide costs and fertilizer application is necessary to create a successful Integrated Weed Management (IWM) system (Jorsgard *et al.*, 1996). In the study by Malik *et al.* (1993), there was a positive effect of using chemical weed control in combination with the cultural control, whereas Gill *et al.* (1997) found that the supply of nitrogen (N) in wheat and barley has a direct effect on weed competition and crop competitiveness, which comprises a major part of IWM. According to Liebman and Janke (1990), an effective fertilization control may be used to minimize the weed interference. The loss of yield due to weeds can be up to 48.9% (Metwally *et al.*, 2000), but there is a great enhancement of grain yield of barley by the use of nitrogen fertilization. Even though the positive impacts of nitrogen on barley productivity are well known, more research is still required to establish the best amounts of nitrogen (Megahed, 2003). As the presence and availability of manual labor becomes particularly rare and expensive, herbicides have been adopted as the cost-efficient mode of controlling barley field weeds. El-Bawab and Kholousy (2003) discovered that the herbicidal weed control resulted in a gain of grain yield by 40.3% and 13.6% of the grain yield of unweeded and hand-weeded plots, respectively. Yousef *et al.* (2004) also noted that the application of nitrogen was quite effective in raising the yields of barley grains and straw, in addition to the percentage of protein. According to El-Metwally *et al.* (2010), the combination of isoproturon and diflufenican was the most successful, which reduced the total number of weeds and dry mass by more than 90% over unweeded slopes, and barley growth, yield, and grain structure. With this combination, the yield of grain by 66.3 percent more than in the weedy check, which was better than other herbicides and hand weeding. Harker *et al.* (2013) also observed that the application of fertilizers without the use of herbicides increases weed interference in barley, but the rate of fertilizer, seed, and herbicides can be used to achieve a competitive crop canopy and manage weeds well.

Conclusion

Barley is a widely used cereal crop that is grown under a wide range of agro-climatic conditions, yet its yield can be limited by the issue of weed infestation and poor nutrient management. Weed and nutrient management have become a sustainability and holistic approach to improve the growth of barley, yield, and resource-use efficiency without affecting soil health. The assessment of multiple studies demonstrates that integrated weed management practices (IWM), which involve the integration of a combination of cultural, mechanical, biological, and chemical control measures, are more effective in lessening the weed density and biomass than the single control measures. On the same note, integrated nutrient management (INM), which involves the combination of organic manures, biofertilizers, and inorganic fertilizers, increases nutrient availability, uptake, and soil microbial activity, resulting in improved crop performance. Management of nutrients and weed interaction is important in defining crop competitiveness. Joint nutrient provision would increase the vigor of the crop and inhibit the growth of weeds through effective usage of the resources. Conversely, unregulated competition of the weed will cause high nutrient loss in the rhizosphere, which will lower the potential of barley yield. Combined strategies reduce such losses by other means, as well as enhancing physiological efficiency and grain quality as well as attributes. Besides, the combination of site-selected herbicide application and organic nutrient input assists in sustaining the ecological balance and minimizes the environmental impact of conventional agriculture. Conclusively, integrated weed and nutrient management of barley production is a method guaranteed to guarantee sustainable productivity and enhanced soil fertility as well as economic profitability. The need to develop region-specific models, precision-based nutrient and weed management tools, and environmentally friendly technologies to improve the performance of integrated practices is an area of future studies. The strategies will be critical in ensuring long-term sustainability, conservation of resources, and resilience of barley-based cropping systems to changing climatic conditions.

References

Agarwal, S. B., Singh, A., & Dwivedi, G. (2003). Effect of vermicompost, farmyard manure, and chemical fertilizers on growth and yield of wheat (*Triticum aestivum* L. var. HP 2643). *Plant Archives, 3*(1), 9–14.

Aher, S. B., Lakaria, B. L., Kaleshananda, S., Singh, A. B., Ramana, S., Ramesh, K., & Thakur, J. K. (2015). Effect of organic farming practices on soil and performance of soybean (*Glycine max*) under semi-arid tropical conditions in Central India. *Journal of Applied and Natural Science, 7*(1), 67–71.

Al-Johani, N. S., Aytah, A. A., & Boutraa, T. (2012). Allelopathic impact of two weeds, *Chenopodium murale* and *Malva parviflora,* on growth and photosynthesis of barley (*Hordeum vulgare*). *Pakistan Journal of Botany, 44*(6), 1865–1872.

Alshallash, K. S. (2015). Assessment of pre-emergence and post-emergence herbicides in controlling Italian ryegrass growing with barley. *Journal of Applied Sciences Research, 11*(13), 1–5.

Andreasen, C., & Stryhn, H. (2009). Increasing weed flora in Danish beet, pea, and winter barley fields. *Crop Protection, 36*, 11–17.

Angiras, N. N., & Singh, C. M. (1989). Influence of weed control method, plant population, fertility levels, and cropping system on weed management in maize. *Indian Journal of Weed Science, 20*(3), 67–72.

Anonymous. (2016–2017). *Agriculture statistics at a glance.* Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Brar, B. S., Singh, J., Singh, G., & Kaur, G. (2015). Effects of long-term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Journal of Agronomy, 5*, 220–238.

Babu, V. M., Mastan Reddy, C., Subramanyan, A., & Balaguravaiah, D. (2007). Effect of integrated use of organic and inorganic fertilizers on soil properties and yield of sugarcane. *Journal of the Indian Society of Soil Science, 55*, 161–166.

Badiyala, D., Verma, S. P., Singh, C. M., & Gautam, S. (1991). Effect of supplemental nitrogen sources and fertilizer nitrogen on weed density and growth in maize + soybean–wheat cropping sequence. *Indian Journal of Weed Science, 23*(1–2), 38–42.

Bajpai, R. K., Chilate, S., Upadhyay, S. K., & Urkurkar, J. S. (2006). Long-term studies on soil physico-chemical properties and productivity of rice–wheat system as influenced by integrated nutrient management in Inceptisol of Chhattisgarh. *Journal of the Indian Society of Soil Science, 54*, 24–29.

Bandyopadhyay, K. K., Misra, A. K., Ghosh, P. K., & Hati, K. M. (2010). Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean. *Soil and Tillage Research, 110*(1), 115–125.

Banga, R. S., & Yadav, A. (2004). Effect of fenoxaprop and sulfosulfuron alone and tank mixture against complex weeds in wheat. *Indian Journal of Weed Science, 36*, 163–165.

Barthwal, A., Bhardwaj, A. K., Chaturvedi, S., & Pandiaraj, T. (2013). Site-specific NPK recommendation in wheat (*Triticum aestivum*) for sustained crop and soil productivity in Mollisols of the Tarai region. *Indian Journal of Agronomy, 58*(2), 208–214.

Bauer, A., Frank, A. B., & Black, A. L. (1987). Aerial parts of hard red spring wheat: I. Dry matter distribution by plant development stage. *Agronomy Journal, 79*, 845–852.

Behara, A. K. (1995). Effect of seed rate, row spacing, and fertilizer on wheat (*Triticum aestivum*). *Indian Journal of Agronomy, 40*(3), 510–511.

Behara, U. K., Sharma, A. R., & Pandey, H. N. (2007). Sustaining productivity of wheat–soybean cropping system through integrated nutrient management practices on the Vertisols of Central India. *Plant and Soil, 297*(1–2), 185–199.

Beyene Dinka, T. A., & Ermiyias, H. H. (2018). Effect of integrated nutrient management on growth and yield of food barley (*Hordeum vulgare*) variety in Toke Kutaye District, West Showa Zone, Ethiopia. *Advances in Crop Science and Technology, 6*(3). https://doi.org/10.4172/2329-8863

Bhaduri, D., & Gautam, P. (2013). Optimization and validation of targeted yield equation-based fertilizer doses under INM for wheat in the Tarai region of Uttarakhand, India. *Indian Journal of Agricultural Research, 47*(1), 16–25.

Bhaduri, D., & Gautam, P. (2013). Balanced use of fertilizers and FYM to enhance nutrient recovery and productivity of wheat (*Triticum aestivum* L. UP-2382) in a Mollisol of Uttarakhand. *Indian Journal of Agricultural Biochemistry, 5*(4), 435–439.

Bhullar, M. S., Kaur, S., Kaur, T., Singh, T., Singh, M., & Jhala, A. J. (2013). Control of broadleaf weeds with post-emergence herbicide in four barley cultivars. *Crop Protection, 43*, 216–222.

Birch, C. J., & Long, K. E. (1990). Effect of nitrogen on the growth, yield, and grain protein content of barley (*Hordeum vulgare* L.). *Australian Journal of Experimental Agriculture, 30*(2), 237–242.

Brady, N. C., & Weil, R. R. (2003). *The nature and properties of soils* (13th ed.). Pearson Education, Singapore Pvt. Ltd., New Delhi, India.

Brar, A. S., & Walia, U. S. (2008). Effect of rice residue management techniques and herbicides on nutrient uptake by *Phalaris minor* and wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science, 40*(3–4), 121–127.

Chaudhary, S. U., Hussain, M., Ali, M. A., & Iqbal, J. (2008). Effect of weed competition period on yield and yield components of wheat. *Indian Journal of Agricultural Research, 46*, 47–53.

Chhokar, R. S., Sharma, R. K., & Verma, R. P. S. (2008). Pinoxaden for controlling grass weeds in wheat and barley. *Indian Journal of Weed Science, 40*, 41–46.

Chhokar, R. S., Sharma, R. K., & Chander, S. (2011). Optimizing the surfactant dose for sulfosulfuron and a ready-mix combination of sulfosulfuron and carfentrazone against weeds in wheat. *Indian Journal of Weed Science, 43*(3–4), 153–162.

Chopra, N., & Chopra, N. K. (2005). Bioefficacy of fenoxaprop, clodinafop, and metribuzin alone and in combination against weeds in wheat and their residual effect on succeeding crops. *Indian Journal of Weed Science, 37*, 163–166.

Chopra, N. K., & Chopra, N. (2010). Evaluation of tillage system and herbicides on wheat (*Triticum aestivum*) performance under rice–wheat cropping system. *Indian Journal of Agronomy, 55*(4), 304–307.

Chopra, N. K., & Chopra, N. (2012). Wheat (*Triticum aestivum*) productivity as affected by application of low-dose herbicides as sole and premix formulations. *Indian Journal of Agronomy, 57*(4), 378–381.

Chopra, N. K., Chopra, N., & Sinha, R. (2008). Influence of new broadleaf herbicides on weed control, seed yield, and quality of some wheat (*Triticum aestivum*) cultivars. *Indian Journal of Agricultural Sciences, 78*(5), 405–407.

Choubey, N. K., Tripathi, R. S., Ghosh, B. C., & Kolhe, S. S. (1998). Influence of fertilizer and weed management practices on weed growth and yield of direct-seeded upland rice. *Oryza, 35*(2), 154–158.

Choudhary, S., Yadav, L. R., Shivran, A. C., & Puniya, M. M. (2014). Effect of fertilizers and manures with foliar application of iron on barley (*Hordeum vulgare* L.). *Green Farming, 5*(1), 41–45.

Cussans, G. W., Cussans, R. D., & Wilson, B. J. (1986). Thresholds for weed control: The concept and its interpretation. In *Proceedings of EWRS Symposium–Economics of Weed Control* (pp. 253–260). EWRS, Stuttgart-Hohenheim, Germany.

Woubshet, D., Selamyihun, K., Tolera, A., & Cherukuri, R. V. (2017). Effects of lime, blended fertilizer (NPSB), an,d compost on yield and yield attributes of barley (*Hordeum vulgare* L.) on acid soils of Wolmera District, West Showa, Ethiopia. *Ethiopian Journal of Applied Science and Technology, 8*(2), 84–100.

Das, T. K. (2008). *Weed Science: Basic and Application* (1st ed.). Jain Brothers Publishers, New Delhi.

Dastgheib, F. (1989). Relative importance of crop seed, manure, and irrigation water as sources of weed infestation. *Weed Research, 29*, 113–116.

Dejene, K. M., & Fetien, A. A. (2014). Growth and yield of barley (*Hordeum vulgare* L.) as affected by nitrogen and phosphorus fertilization and water regimes in Tigray, Ethiopia. *Momona, Ethiopian Journal of Science, 6*(1), 45–57.

Derebe, T., Temesgen, D., & Habtamu, A. (2018). Effect of nitrogen fertilizer levels on grain yield and quality of malt barley (*Hordeum vulgare* L.) varieties at Wolmera District, Central Highland of Ethiopia. *International Journal of Research Studies in Agricultural Sciences (IJRSAS)*, *4*(4), 29–43.

Dhaliwal, S. S., & Walia, S. S. (2008). Integrated nutrient management for sustaining maximum productivity of rice-wheat system under Punjab conditions. *Journal of Research, Punjab Agricultural University*, *45*(1–2), 12–16.

Dhima, K. V., Eleftherohorinos, I. G., & Vasilakoglou, I. B. (2000). Interference between *Avena sterilis*, *Phalaris minor* and five barley cultivars. *Weed Research*, *40*, 549–559.

Dixit, A., & Singh, V. P. (2008). Efficacy of a ready-mix application of carfentrazone plus isoproturon (Affinity) to control weeds in wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, *78*(6), 495–497.

Dodamani, B. M., & Das, T. K. (2009). Interference of common lambsquarters (*Chenopodium album*) in wheat (*Triticum aestivum*) as influenced by nitrogen levels. *Indian Journal of Agronomy*, *54*(3), 310–314.

Doll, H. (1997). The ability of barley to compete with weeds. *Biological Agriculture & Horticulture*, *14*(1), 43–51.

Dubey, L., Dwivedi, A. K., & Dubey, M. (2015). Long-term application of fertilizer and manures on physico-chemical properties and N, P, and K uptake in soybean-wheat cropping system. *Plant Archives*, *15*(1), 143–147.

Dwivedi, D. K., & Thakur, S. S. (2004). Production potential of wheat (*Triticum aestivum*) crop as influenced by residue organics, direct and residual fertility levels under rice-wheat cropping system. *Indian Journal of Agronomy*, *45*(4), 641–647.

Eid, R. A., Sedera, A., & Attia, M. (2006). Influence of nitrogen-fixing bacteria incorporation with organic and inorganic fertilizers on growth, flower yield, and chemical composition of *Celosia argentia*. *World Journal of Agricultural Sciences*, *2*(4), 450–458.

El-Metwally, I. M., Abd El-Salam, M. S., & Tagour, R. M. H. (2010). Nitrogen fertilizer levels and some weed control treatments effects on barley and associated weeds. *Agricultural Biology Journal*, *1*(5), 992–1000.

Fakkar, A. A. O., & Amin, I. A. (2012). Integration between sowing methods and mechanical weed control and their effect on wheat productivity. *Australian Journal of Basic and Applied Sciences*, *6*, 519–529.

Fathi, G. S., Medonall, G. K., & Lanee, R. C. M. (1997). Responsiveness of barley cultivars to nitrogen fertilizer. *Australian Journal of Experimental Agriculture*, *37*(2), 199–211.

Filipov, K. H. (1976). Mineral fertilization of the Aztur barley variety on leached chernozem Smonitsa soil in South East Bulgaria. *Rastenievdni Nauk*, *13*(1), 112–118.

Finker, R. E., & Gledhill, V. H. (1971). Response of irrigated winter wheat and winter barley to different fertility levels on the high plains. *Bulletin, New Mexico State University Agricultural Experiment Station*, No. 576, 1–16.

Georgiev, M., Pavlov, D., Beev, G., Gerdzikova, M., & Bazitov, R. (2011). Species composition of weeds in wheat and barley. *Agricultural Science and Technology*, *3*(2), 143–149.

Gill, H. S., & Brar, L. S. (1975). Importance of herbicides in the agriculture of Punjab and Haryana. *Pesticides*, *9*(4), 20–24.

Gill, H. S., Singh, A., & Walia, U. S. (1984). Tolerance of weed cultivars to metoxuron. *Indian Journal of Weed Science*, *16*, 176–181.

Gill, M. S., Singh, T., & Rana, D. S. (1994). Integrated nutrient management in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping sequence in semi-arid tropics. *Indian Journal of Agronomy*, *39*(4), 606–608.

Girish, G. K., & Chandrashekar, C. P. (2000). Farmers' practices of nutrient management for sugarcane in GLBC area of Karnataka – A status paper. *Co-operative Sugar*, *31*(6), 477–484.

Gomiero, T., Pimentel, D., & Paoletti, M. G. (2011). Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. *Critical Reviews in Plant Sciences*, *30*(1–2), 95–124.

Gupta, R. K., Paradkar, V. K., Raghuvanshi, R. K. S., & Rande, D. H. (1990). Effect of depth and frequency of irrigation on the performance of wheat growth on a sodic typic chromustert. *Indian Journal of Soil Science*, *34*, 1–4.

Gupta, V., & Sharma, R. (2007). Effect of integrated nutrient management on productivity and balance of rice-wheat cropping system. *Annals of Plant and Soil Research*, *8*(2), 148–151.

Hansram, M., Choudhary, J., Kumar, A., Singh, A., & Chopra, R. (2017). Growth, quality and yield of barley (*Hordeum vulgare* L.) as influenced by varieties and precision nutrient management practices. *Journal of Pharmacognosy and Phytochemistry*, *6*(3), 35–41.

Hansram, M., Choudhary, J., Singh, D., & Chopra, R. (2017). Yield, nutrient content and uptake of barley (*Hordeum vulgare* L.) as influenced by varieties and precision nutrient management practices. *International Journal of Current Microbiology and Applied Sciences*, *Special Issue–4*, 156–164.

Harmon, G. W., & Keim, F. D. (1934). The percentage and viability of weed seeds recovered in the faeces of farm animals and their longevity when buried in manure. *Agronomy Journal*, *26*, 762–767.

Hawes, C., Squire, G. R., Hallett, P. D., Watson, C. A., & Young, M. (2010). Arable plant communities as indicators of farming practice. *Agriculture, Ecosystems & Environment*, *138*(1–2), 17–26.

Hesse, P. R. (1984). Potential of organic materials for soil improvement. In *Organic Matter and Rice* (pp. 35–43). IRRI.

Howalt, K. A. (2005). Carfentrazone-ethyl injury to spring wheat (*Triticum aestivum* L.) is minimized by some ALS-inhibiting herbicides. *Weed Technology*, *19*, 777–783.

Husain, K., Dubey, S. D., Verma, R. C., Tripathi, A. K., & Pandey, R. K. (2015). Effect of weed management with post-emergence herbicides on seed yield, net return, and oil quality of barley (*Hordeum vulgare* L.). *Current Advances in Agricultural Sciences*, *7*(2), 120–124.

Jackson, M. L. (1967). *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Jain, V., Jain, N., & Kewat, M. L. (2014). Effect of application of post-emergence herbicides at different levels of available soil moisture content in irrigated wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, *59*(1), 91–95.

Jarwar, A. D., Tunio, S. D., Majeedano, H. I., & Kaisrani, M. A. (1999). Efficiency of different weedicides in controlling weeds of wheat. *Pakistan Journal of Agricultural, Agricultural Engineering and Veterinary Science*, *15*(2), 17–20.

Jat, G., Majumdar, S. P., Jat, N. K., & Majumdar, S. P. (2013). Potassium and zinc fertilization of wheat (*Triticum aestivum*) in the Western arid zone of India. *Indian Journal of Agronomy, 58*(1), 67–71.

Jat, R. K., Punia, S. S., & Malik, R. K. (2007). Effect of different herbicide treatments on nutrient uptake behavior of weeds and wheat (*Triticum aestivum*). *Indian Journal of Weed Science, 39*(1–2), 135–137.

Jonson, L., & Johnson, O. (1975). Effect of nitrogen fertilization on protein content and quality of barley grain. *Lantbrukshögskolans Meddelanden, 248*, 64.

Joshi, N. C. (2002). *Manual of weed control.* Research Publication, 7615-B, East Azadnagar, Delhi–110051.

Kathuria, M. K., Singh, H., Singh, K. P., & Kadian, V. S. (2004). Effect of integrated nutrient management on N and P content and uptake by wheat under cereals–fodder–wheat cropping system. *Research on Crops, 5*(1), 31–35.

Katiyar, A. K., & Uttam, S. K. (2008). Effect of fertility levels and weed control practices on nutrient uptake and yield of rainfed barley in eroded soils of Central U.P. *Indian Agriculturist, 52*(1–2), 17–21.

Ketema, N., & Mulatu, K. (2018). Response of food barley (*Hordeum vulgare* L.) varieties to rates of nitrogen fertilizer in Limo District, Hadiya Zone, Southern Ethiopia. *Journal of Natural Sciences Research, 8*(15).

Khippal, A., Kharub, A., Kumar, D., Verma, A., Kumari, S., & Kumar, Y. (2016). Pinoxaden in combination with other herbicides against complex weed flora in barley. *International Journal of Tropical Agriculture, 34*(3), 805–809.

Kumar, R., Singh, U. P., & Mahajan, G. (2017). Residue and weed management practices in zero-till wheat (*Triticum aestivum*) under rice–wheat cropping system. *International Journal of Agriculture Sciences, 9*(4), 3708–3712.

Kumar, S. (2004). *Effect of different levels of irrigation and nitrogen levels on barley (Hordeum vulgare L.) var. K-551* (M.Sc. Thesis). Department of Agronomy, CSAUA&T, Kanpur.

Kumar, S., Bhattoo, M. S., Punia, S. S., & Singh, S. (2010). Evaluation of pinoxaden in combination with 2,4-D against complex weed flora in barley. *Indian Journal of Weed Science, 42*(1–2), 120–122.

Kumar, V., Khippal, A., Singh, J., Selvakumar, R., Malik, R., Kumar, D., Kharub, A. S., Verma, R. P. S., & Sharma, I. (2014). Barley research in India: Retrospect and prospects. *Journal of Wheat Research, 6*(1), 1–20.

Kumpawat, B. S. (2009). Effect of soil alkali water conditions amelioration on nitrogen, growth, and yield of barley (*Hordeum vulgare*). *Haryana Journal of Agronomy, 25*(1–2), 35–38.

Liebman, M., & Davis, A. (2000). Integration of soil, crop, and weed management in low-external-input farming systems. *Weed Research, 40*(1), 27–47.

Luebs, R. E., & Laag, A. E. (1967). Nitrogen effect on leaf area, yield, and nitrogen uptake of barley under moisture stress conditions. *Agronomy Journal, 59*, 219–222.

Mairan, N. R., Dhawa, A. S., Zote, A. K., Patil, S. G., & Jeughale, J. S. (2016). Effect of organic and inorganic sources of nutrients on the physico-chemical properties under different cropping systems in Vertisol. *Journal of the Indian Society of Soil Science, 34*(6), 1575.

Malik, B. L. (1971). Response of barley to soil moisture regimes and nitrogen levels. *Indian Journal of Agronomy, 16*, 43–45.

Malik, R. S., Yadav, S. K., Malik, R. K., Singh, D. P., & Rathee, S. S. (1993). Effect of tribenuron and fertility levels for weed control in wheat. *Proceedings of the Indian Society of Weed Science International Symposium* (p. 83–85). Hisar, India.

Malik, R. S., Yadav, A., & Kumar, R. (2013). Ready mix formulation of clodinafop-propargyl + metsulfuron-methyl against complex weed flora in wheat. *Indian Journal of Weed Science, 45*(3), 179–182.

Meena, B. L., Phogat, B. S., Jat, S. L., Singh, A. K., & Sharma, H. B. (2012). Effects of planting and integrated nutrient management systems on root phenology and grain yield of wheat. *Extended Summaries of the 3rd International Agronomy Congress*, New Delhi, India, November 26–30.

Meena, R. S., & Singh, M. K. (2011). Weed management in late sowing zero-till wheat (*Triticum aestivum*) with varying seed rate. *Indian Journal of Agronomy, 56*(2), 127–132.

Megahed, M. A. (2003). Effect of seeding rate and nitrogen fertilizer level on newly hull-less barley under sprinkler irrigation system in poor sandy soil at Ismailia Governorate. *Egyptian Journal of Applied Sciences, 18*(2), 108–119.

Mesfin, K., & Zemach, S. (2015). Effect of nitrogen and phosphorus fertilizer rates on yield and yield components of barley (*Hordeum vulgare* L.) varieties at Damot Gale District, Wolaita Zone, Ethiopia. *American Journal of Agriculture and Forestry, 3*(6), 271–275.

Metwally, G. M., Hassan, A. A. A., & Ahmed, S. A. (2000). Influence of some herbicides on barley yield and yield components and the common associated weeds. *Journal of*

Agricultural Science, Mansoura University, 25(10), 6009–6019.

Mitiku, W., Temedo, T., Singh, T. N., & Teferi, M. (2014). Effect of integrated nutrient management on yield and yield components of barley (*Hordeum vulgare* L.) in Keffa Zone, Southwestern Ethiopia. *Science, Technology and Arts Research Journal, 3*(2), 34–42.

Mohanty, A. K., *et al*. (2015). Precision nitrogen management practices influence the growth and yield of wheat (*Triticum aestivum*) under conservation agriculture. *Indian Journal of Agronomy, 60*(4), 617–621.

Mubarak, T., & Singh, K. N. (2011). Nutrient management and productivity of wheat (*Triticum aestivum*) based cropping system in the temperate zone. *Indian Journal of Agronomy, 56*(3), 176–181.

Mukhopadhyay, S. K., & Bera, P. S. (1980). Effectiveness of basalin, isoproturon, and cultural methods in controlling weeds in wheat. *Crop Pesticides, 14*, 21–23.

Nambiar, K. K. M., & Abrol, I. P. (1992). Long-term fertilizer experiments in India: An overview. *Fertilizer News, 34*(4), 11–20.

Narolia, G. P. (2009). *Response of malt barley (Hordeum vulgare L.) to levels and scheduling of nitrogen application under varying growing environments* (Ph.D. Thesis). Department of Agronomy, SKRAU, Bikaner.

Negi, S. C., & Chopra, P. (2015). Management of mixed weed flora in barley with tank mix application of isoproturon with metsulfuron and 2,4-D. *Indian Journal of Weed Science, 47*(1), 28–30.

Oerke, E. C., Dehne, H. W., Schönbeck, F., & Weber, A. (1994). *Crop production and crop protection: Estimated losses in major food and cash crops.* Elsevier Science, Amsterdam, The Netherlands.

Paighan, V. B., Gore, A. K., & Chavan, A. S. (2013). Effect of new herbicides on growth and yield of wheat. *Indian Journal of Weed Science, 45*(4), 291–293.

Palaniappan, S. P., & Annadurai, K. (2007). *Organic farming: Theory and practices.* Scientific Publishers, Jodhpur, pp. 169.

Pandey, I. B., Dwivedi, D. K., & Pandey, R. K. (2009). Integrated nutrient management for sustaining wheat (*Triticum aestivum*) production under late sown conditions. *Indian Journal of Agronomy, 54*(3), 306–309.

Pandey, I. B., Mishra, S. S., Singh, H., & Prasad, N. (2000). Nutrient uptake by wheat (*Triticum aestivum* L.) and associated weeds as influenced by fertilizer levels and weed management. *Indian Journal of Weed Science, 32*(1&2), 31–34.

Pandey, I. B., Sharma, S. L., Tiwari, S., & Bharati, V. (2001). Effect of tillage and weed management on grain yield and nutrient removal by wheat and weeds. *Indian Journal of Weed Science, 33*(3&4), 107–111.

Pandey, L. B., Dwivedi, D. K., & Prakash, S. C. (2006). Impact of method and levels of fertilizer application and weed management on nutrient economy and yield of wheat (*Triticum aestivum* L.). *Indian Journal of Agronomy, 51*(3), 193–198.

Pandey, L. B., Dwivedi, D. K., & Prakash, R. K. (2007). Efficiency of herbicide and fertilizer management on weed dynamics in wheat (*Triticum aestivum*). *Indian Journal of Agronomy, 52*(1), 49–52.

Pandey, L. B., Singh, H., & Tiwari, S. (2003). Response of timely sown wheat to levels and time of nitrogen application. *Journal of Research, RAU, 15*(1), 35–38.

Paramjit, & Singh, V. P. (2002). Effect of different levels of nitrogen and irrigation on nitrogen uptake and quality of malt barley. *Research on Crops, 21*(2), 120–122.

Pardo, G., Riravololona, M. J., Petit, M. S., Farcy, P., & Munier-Jolain, N. (2008). Effects of integrated weed control on labour organization and economic profitability of farms. *ITEA - Información Técnica Económica Agraria, 104*(4), 448–471.

Paswan, A. K., Kumar, R., Kumar, P., & Singh, R. K. (2012). Influence of metsulfuron-methyl and carfentrazone-ethyl, either alone or in combination, on weed flora, crop growth, and yield in wheat (*Triticum aestivum*). *Madras Agricultural Journal, 99*(7–9), 560–562.

Patel, R. M., & Upadhayay, P. N. (1993). Response of wheat to irrigation under varying levels of nitrogen and phosphorus. *Indian Journal of Agronomy, 38*(1), 113–114.

Patel, S. M., Patel, J. C., Chaudhary, P. P., Patel, D. M., Patel, G. N., & Patel, B. M. (2012). Effects of nitrogen levels and weed management on production potential of wheat (*Triticum aestivum* L.). *Research on Crops, 13*(2), 456–462.

Prameela, P., Menon, S. S., & Menon, M. V. (2014). Effect of new post-emergence herbicides on weed dynamics in wet-seeded rice. *Journal of Tropical Agriculture, 52*(1), 94–100.

Prasad, B., & Prasad, J. (1998). Effective and efficient use of fertilizer for wheat growth in Alfisol using the targeted yield concept. *Fertilizer News, 43*(8), 37–40.

Prasad, J., Karmakar, S., Kumar, R., & Mishra, B. (2010). Influence of integrated nutrient management on yield and soil properties in maize–wheat cropping system in an Alfisol of Jharkhand. *Journal of the Indian Society of Soil Science, 58*(2), 200–204.

Punia, S. S., Singh, S., Yadav, D. B., & Kumar, S. (2009). Distribution of weed flora of barley in south-western Haryana. *Haryana Journal of Agronomy, 25*(1–2), 91–93.

Puniya, M. M., Yadav, S. S., & Shivran, A. C. (2015). Productivity, profitability, and nitrogen use efficiency of barley (*Hordeum vulgare*) as influenced by weed management and nitrogen fertilization under hot semi-arid ecologies of Rajasthan. *Indian Journal of Agronomy, 60*(4), 564–569.

Ram, T., & Mir, M. S. (2006). Effect of integrated nutrient management on yield and yield-attributing characters of wheat (*Triticum aestivum*). *Indian Journal of Agronomy, 51*(3), 189–192.

Ram, H., & Singh, A. (2009). Studies on efficacy of tank mix herbicides for the control of weeds in irrigated barley (*Hordeum vulgare* L.). *Indian Journal of Weed Science, 41*(3&4), 167–171.

Ram, H., & Dhaliwal, S. S. (2012). Effect of varieties and integrated nutrient management techniques on growth, productivity, quality, and economics of barley (*Hordeum vulgare* L.). *International Journal of Agricultural Sciences, 8*(1), 91–97.

Rao, V. S. (1994). *Principles of weed science.* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, p. 540.

Rao, V. S. (2001). *Principles of weed science* (2nd ed.). Oxford and IBH Publishing Co., New Delhi, pp. 2–3.

Roy, D. K., Singh, B. P., & Singh, P. (2004). Effect of vermicompost and fertility levels on growth, yield, and yield attributes of malt barley (*Hordeum vulgare* L.). *Annals of Agricultural Research, 25*(1), 87–91.

Roy, R. K., & Singh, B. K. (1989). Response of hull-less barley to fertilizer application under the rainfed situation of diara land. *Indian Journal of Agronomy, 34*(4), 480–482.

Shejbalová, S., Cerný, J., Vasak, F., Kulhánek, M., & Balík, J. (2014). Nitrogen efficiency of spring barley in a long-term experiment. *Plant, Soil and Environment, 60*(7), 291–296.

Singh, S. B. (2017). Effect of integrated nutrient management on barley (*Hordeum vulgare* L.) under the north-western plain zone of Uttar Pradesh, north-west India. *Indian Journal of Fertilizers, 10*(2), 52–54.

Sepat, R. N., Rai, R. K., & Dhar, S. (2010). Planting systems and integrated nutrient management for enhanced wheat (*Triticum aestivum*) productivity. *Indian Journal of Agronomy, 55*(2), 114–118.

Sharma, J. P. (1981). Role of FYM in economizing the use of fertilizers in a cropping sequence (wheat–mungbean). *Indian Journal of Agronomy, 26*(2), 171–174.

Sharma, V. K., Pandey, R. N., & Sharma, B. M. (2015). Studies on the long-term impact of STCR-based integrated fertilizer use on pearl millet (*Pennisetum glaucum*)–wheat (*Triticum aestivum*) cropping system in semi-arid conditions of India. *Journal of Environmental Biology, 36*(1), 241–247.

Shekhawat, R. P. S., & Sevnewat, P. S. (2010). Soil fertility status affected with and without farmyard manure in kharif crops and fertilizer levels in barley (*Hordeum vulgare*). *Indian Journal of Agricultural Sciences, 80*(9), 791–794.

Shoeran, S., Punia, S. S., Yadav, A., & Singh, S. (2013). Bioefficacy of pinoxaden in combination with other herbicides against complex weed flora in wheat. *Indian Journal of Weed Science, 45*(2), 90–92.

Singh, F., Kumar, R., & Pal, S. (2008). Integrated nutrient management in rice–wheat cropping system for sustainable productivity. *Journal of the Indian Society of Soil Science, 56*(2), 205–208.

Singh, G., Singh, O. P., Singh, R. G. S., Mehta, R. K., Kumar, V., & Singh, R. P. (2006). Effect of integrated nutrient management on yield and nutrient uptake of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in lowlands of Eastern Uttar Pradesh. *Indian Journal of Agronomy, 51*(2), 85–85.

Singh, G., & Singh, P. V. (2005). Compatibility of clodinafop-propargyl and fenoxaprop-p-ethyl with carfentrazone-ethyl, metsulfuron-methyl, and 2,4-D. *Indian Journal of Weed Science, 37*(1&2), 1–5.

Singh, N. P., Sachan, R. S., Pandey, P. C., & Bisht, P. S. (1999). Effect of decade-long fertilization and manure application on soil fertility and productivity of rice–wheat system in a Mollisol. *Indian Journal of Soil Science, 47*(1), 34–37.

Singh, R., Singh, B., & Patidar, M. (2008). Effect of preceding crops and nutrient management on productivity of wheat (*Triticum aestivum*) based cropping system in an arid region. *Indian Journal of Agronomy, 53*(4), 267–272.

Singh, R. K., Singh, S. K., & Singh, L. B. (2007). Integrated nitrogen management in wheat (*Triticum aestivum*). *Indian Journal of Agronomy, 52*(2), 124–126.

Singh, R. P., Prasad, M., & Kaushik, K. S. (1971). Effect of different levels of nitrogen and phosphorus on the yield of barley. *Indian Journal of Agronomy, 16*, 123–125.

Singh, S., & Punia, S. S. (2007). Sensitivity of barley to herbicides of different modes of action. *Indian Journal of Weed Science, 39*(3&4), 205–210.

Singh, S., Malik, R. K., Balyan, R. S., & Singh, S. (1995). Distribution of weed flora of wheat in Haryana. *Indian Journal of Weed Science, 27*, 114–121.

Singh, S., Punia, S. S., Balyan, R. S., & Malik, R. K. (2008). Efficacy of tribenuron-methyl applied alone and in tank mix against broadleaf weeds of wheat (*Triticum aestivum*). *Indian Journal of Weed Science, 40*(3&4), 109–120.

Singh, S., Satyavan, Balyan, R. S., Duhan, B. S., & Yadav, M. R. (2003). Nutrient uptake by weeds and barley cultivars as influenced by weed management practices. *Annals of Agricultural and Biological Research, 8*(1), 9–11.

Singh, S. P., & Pal, M. S. (2011). Effect of integrated nutrient management on productivity, quality, nutrient uptake, and economics of mustard (*Brassica juncea*). *Indian Journal of Agronomy, 56*(4), 381–387.

Singh, S. P., & Singh, K. P. (2003). Effect of integrated nutrient management on productivity, quality, nutrient uptake and economics of mustard (*Brassica juncea*). *Indian Journal of Agronomy, 56*(4), 381–387.

Singh, S. (2009). Synergy of tank mix application of herbicides on *Cirsium arvense* under non-cropped situation. *Indian Journal of Weed Science, 41*, 88–95.

Singh, S., Yadav, A., Punia, S. S., Malik, R. S., & Balyan, R. S. (2010). Interaction of stage of application and herbicides on some *Phalaris minor* populations. *Indian Journal of Weed Science, 42*, 144–154.

Singh, S., Punia, S. S., Yadav, A., & Hooda, V. S. (2011). Evaluation of carfentrazone-ethyl + metsulfuron-methyl against broadleaf weeds of wheat. *Indian Journal of Weed Science, 43*(1&2), 12–22.

Singh, S., Singh, R. N., Prasad, J., & Singh, B. P. (2006). Effect of integrated nutrient management on yield and uptake of nutrients by rice and soil fertility in rainfed uplands. *Indian Journal of Soil Science, 54*(3), 327–330.

Singh, V., Singh, B., Singh, Y., Thind, H. S., & Gupta, R. K. (2010). Need-based nitrogen management using the chlorophyll meter and leaf colour chart in rice and wheat in South Asia: A review. *Nutrient Cycling in Agroecosystems, 88*, 361–380.

Sirazuddin, S. P., Singh, V. P., Singh, B. S., Mahapatra, H., & Verma, H. (2017). Effect of establishment methods and weed-control measures on broadleaf weeds, yield attributes, and harvest index of wheat (*Triticum aestivum*). *International Journal of Engineering Research & Science, 6*(S).

Sood, B. R., Singh, R., & Sharma, V. K. (1993). Effect of nitrogen on growth and fodder yield of barley (*Hordeum vulgare*) varieties under rainfed conditions. *Indian Journal of Agronomy, 38*(4), 653–654.

Sridevi, V., Jeyaraman, S., Chinnusamy, C., & Chellamuthu, V. (2013). Weed management in lowland rice (*Oryza sativa* L.) ecosystem: A review. *International Journal of Agricultural Science and Research (IJASR), 3*(3), 13–22.

Stonehouse, D. P., Weise, S. F., Sheardown, T., Gill, R. S., & Swanton, C. J. (1996). A case study approach to comparing weed management strategies under alternative farming systems in Ontario. *Canadian Journal of Agricultural Economics, 44*(1), 81–99.

Swezey, S. L., Goldman, P., Bryer, J., & Nieto, D. (2007). Six-year comparison between organic, IPM, and conventional cotton production systems in the northern San Joaquin Valley, California. *Renewable Agriculture and Food Systems, 22*(1), 30–40.

Thakur, R. K., Sawarkar, S. D., Vaishya, U. K., & Singh, M. (2011). Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean–wheat intensive cropping of a Vertisol. *Journal of the Indian Society of Soil Science, 59*(1), 74–81.

Tomar, S. S., & Vivek. (2003). Effect of herbicides on *Phalaris minor* and wheat yield. *Indian Journal of Weed Science, 35*(3/4), 255–256.

Torner, C., Fernandez, Q., & Navarrete, L. (1984). Tolerance and competitive ability of winter cereal cultivars in the presence of *Avena sterilis* L. ssp. *Ludoviciana* Dur. In *Proceedings of the 3rd EWRS Symposium on Weed Problems in the Mediterranean Area* (p. 109). Oeiras, Portugal.

Tripathi, M. K., Chaturvedi, S., Shukla, D. K., & Mahapatra, B. S. (2010). Yield performance and quality in Indian mustard (*Brassica juncea*) as affected by integrated nutrient management. *Indian Journal of Agronomy, 55*(2), 138–142.

Tuti, M. D., & Das, T. K. (2011). Carry-over effect of metribuzin applied to soybean (*Glycine max*) on weeds and wheat (*Triticum aestivum*) under zero and conventional tillage. *Indian Journal of Agronomy, 56*(2), 121–126.

Tyagi, F. (2006). *Integrated nutrient management in wheat* (M.Sc. thesis). Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, India.

Upasani, R. R., Thakur, R., Puran, A. N., & Singh, M. K. (2013). Effect of nitrogen and weed control on the productivity of wheat. *Indian Journal of Weed Science, 45*(2), 106–108.

Usadadiya, V. P., & Patel, R. H. (2013). Influence of preceding crops and nutrient management on productivity of wheat (*Triticum aestivum*) based cropping system. *Indian Journal of Agronomy, 85*(1), 15–18.

Valverde, B. E. (2003). Herbicide resistance management in developing countries. *FAO Plant Production and Protection Paper, 120*, 223–244.

Varshney, J. G., & Prasad, B. M. B. (2008). Future scenario of weed management in India. *Indian Journal of Weed Science, 40*(1&2), 1–9.

Veres, T., & Tyr, S. (2011). The top 10 of most dangerous weed species in the spring barley canopies during the last decade in the Slovak Republic. *Research Journal of Agricultural Science, 43*(2), 119–122.

Verma, G., & Mathur, A. K. (2009). Effect of integrated nutrient management on active pools of soil organic matter under maize–wheat system of a Typic Haplustept. *Journal of the Indian Society of Soil Science, 57*(3), 317–322.

Verma, G., Mathur, A. K., Bhandari, S. C., & Kanthaliya, P. C. (2010). Long-term effect of integrated nutrient management on properties of a Typic Haplustept under maize–wheat cropping system. *Journal of the Indian Society of Soil Science, 58*(3), 299–302.

Walia, U. S., Brar, L. S., & Mehra, S.P. (1990). Interaction effects of nitrogen levels and weed control measures in wheat. *Indian Journal of Weed Science, 22*, 28–33.

Willis, J. B., Askew, S. D., & McElroy, J. S. (2007). Improved white clover control with mesotrione by tank mixing bromoxynil, carfentrazone, and simazine. *Weed Technology, 21*(4), 739–743.

Woubshet, D., Selamyihun, K., Tolera, A., & Raghavaiah, C. V. (2017). Effects of lime, blended fertilizer (NPSB), and compost on yield and yield attributes of barley (*Hordeum vulgare* L.) on acid soils of Wolmera District, West Showa, Ethiopia. *Ethiopian Journal of Applied Science and Technology, 8*(2), 84–100.

Yadav, D. B., Punia, S. S., Yadav, A., & Lal, R. (2009). Compatibility of sulfosulfuron with carfentrazone-ethyl for the control of complex weed flora in wheat. *Indian Journal of Weed Science, 41*(1–2), 146–149.

Yadav, D. S., Shukla, S., & Kumar, B. (2005). Effect of zero tillage and nitrogen level on wheat (*Triticum aestivum*) after rice (*Oryza sativa*). *Indian Journal of Agronomy, 50*(1), 52–53.

Yadav, M. P., Adlam, M., & Kushwaha, S. P. (2005). Effect of integrated nutrient management in rice (*Oryza sativa*)–wheat (*Triticum aestivum* L.) cropping system in the central plain. *Indian Journal of Agronomy, 50*(2), 97–100.

Yaduraju, N. T., Prasad Babu, M. B. B., & Chandra, P. (2006). Herbicide use in agriculture and the environment. In M. S. Swaminathan & K. L. Chadha (Eds.), *Proceedings on agricultural environment management* (pp. 192–210). Malhotra Publishing House, New Delhi, India.

Yawalkar, K. S., Agarwal, J. P., & Bokde, S. (1992). *Manures and fertilizers.* Kapoor Art Press, New Delhi.

Youssef, S. A., El-Sheref, E. E., El-Hag, A. A., & Khder, R. A. A. (2004). Effect of nitrogen fertilizer levels and biofertilization sources on two barley cultivars. *Journal of Agricultural Science, Mansoura University, 29*(12), 6787–6808.