“Effect of fertilizer levels and herbicides on wild oat management in wheat”

By

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CERTIFICATE-I

This is to certify that the thesis entitled **"Effect of fertilizer levels and herbicides on wild oat management in wheat"** submitted for the degree of **Doctor of Philosophy** in the subject of **Agronomy** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Mr. Pavankumar Goudar** under my supervision and that no part of the thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled **“Effect of fertilizer levels and herbicides on wild oat management in wheat”** submitted by **Mr. Pavankumar Goudar** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirement for the degree of **Ph.D.** in the subject of **Agronomy** has been approved by the student's advisory committee after an oral examination on the same.

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LIST OF ABBREVIATIONS

Abbreviation	Expansions
ACCase	Acetyl-CoA carboxylase
ALS	Acetolactate synthase
ANOVA	Analysis of variance
Anon.	Anonymous
@	At the rate of
^0C	Degree Celsius
^0N	Degree north
B:C	Benefit cost ratio
%	Per cent
CD	Critical difference
DAS	Days after sowing
DAP	Di ammonium phosphate
DM	Dry matter
dS m^{-1}	Deci-Siemen per meter
EC	Electrical conductivity
E	Evening
et al.	(et alia) and other people
fb	Followed by
Fig	Figure
g	Gram
g ha^{-1}	Gram per hectare
g m^{-2}	Gram per square meter
ha	Hectare
K	Potassium
Kg ha^{-1}	Kilogram per hectare
l	Litre
m	Meter
M	Morning
Max.	Maximum
Min.	Minimum
ml	Milliliter

mm	Millimeter
ME	Micro-encapsulated
MOA	Mode of action
N	Nitrogen
NS	Non-significant
P	Phosphorus
P.T	Productive tiller
P_2O_5	Ortho phosphate
K_2O	Potassium oxide
psi	Pascal per square inch
POE	Post-emergence
PRE	Pre-emergence
PSII	Photosystem II
RDF	Recommended dose of fertilizer
RH	Relative humidity
Rs.	Rupees
SE(m)	Standard error of mean
Temp.	Temperature
WDG	Water Dispersible Granules
WG	Wettable Granules
WP	Wettable Powder
WCE	Weed control efficiency
WI	Weed index
*	Significant at 5 % probability

CHAPTER–I

INTRODUCTION

Wheat (*Triticum aestivum* L.), the king of cereals, originated from the Levant region of the North-East Asia; is one of the most important cereal crops of the world grown in 122 countries and plays an important role in the agricultural system of northern India. Due to its wide adaptability, it can be grown under various agro climatic conditions and compares well with other important cereals in its nutritive value; it contains 11 % to 12 % protein which is highest among all cereals. It belongs to the family Poaceae and genus *Triticum*. Through evolution and domestication, wheat got modified from diploid to tetraploid to finally hexaploid species. In India, only three species of wheat namely *Triticum aestivum* (common bread wheat), *Triticum durum* (Macroni or durum wheat) and *Triticum dicoccum* (Emmer wheat) are economically important. This crop has contributed immensely to the advent and flourishment of green revolution, increasing production by six times in comparison to that of 1960's. The production of wheat in the country has increased significantly from 75.8 mt in 2006-07 to an all-time record high of 95.8 mt in 2013-14.

Wheat is the world's second most important cereal crop after rice, cultivated on an area of about 224 mha with a grain production of 753 mt during 2016-17 (Anonymous, 2017a), India is the second largest producer of wheat with 30.59 mha area with a production of 98.38 mt and productivity of 3216 kg ha^{-1} (Anonymous, 2017b). The area under wheat in Haryana is 2.58 mha which is 8.5 % of total wheat area at national level with production of 11.3 mt contributing 12.0 % of total wheat production in India with productivity of 4407 kg ha^{-1} (Anonymous, 2017b).

There is greater scope to increase wheat productivity by bridging the gap between potential and achieved yield. Wheat productivity is a result of many factors, but weed management is one of the major and less cared causes of low yield. Wild oat (*Avena ludoviciana*) and wild canary grass (*Phalaris minor)* are two dominant grassy weeds making wheat cultivation less remunerative due to significant yield losses (Singh *et al*., 1995 and Singh *et al*., 1999). Wild oat is more competitive than little seed canary grass as it emerges early and competes more vigorously with wheat. Moreover, it responds more favorably to fertilizers and irrigation. Therefore, not only weed biology, but also the knowledge about the herbicides and nutrients synergy is vital to promote the crop growth in getting higher yield of wheat (Goudar *et al*., 2017).

Weeds are always considered as harmful plants and biggest threats to agriculture (Singh *et al.*, 2005 and Singh, 2007). Among several constraints of wheat production, weeds are one of the major constraints causing yield losses ranges from 10–82 % depending upon the density and species of weed, duration of infestation and competing ability of crop plants under different agro-ecological conditions (Heyne, 1987). The presence of weeds in a crop can adversely affect production in a number of ways. Weeds use the soil fertility, available nutrients, moisture and compete for space and sunlight with the crop plants. This not only results in yield reduction but also deteriorates the quality of the produce (Singh and Malik, 1992), hence reducing the market value of crops. It has been estimated that crop losses due to weed competition throughout the world as a whole are greater than those resulting from the combined effects of insect pests and diseases. There are thus several reasons for entirely eliminating or effectively managing the weeds from the crop environment.

Wild oat is the most prevalent winter annual grass in winter wheat fields of northern India and worldwide (Singh *et al*., 1995). It germinates along with wheat, grows quickly, establishes a deep and extensive root system and responds dramatically well to the higher levels of nitrogen and considered as the 13th most important weed worldwide and most competitive weed in agricultural crops including wheat, all over India (Khan *et al*., 2006). A lower temperature around 25^{0}C and moist soils, prevalent in the spring and early autumn, favour germination and emergence of *A. ludoviciana*, and seeds buried as deep as 20 cm can emerge (Singh *et al.*, 2010). Seeds of *A. ludoviciana* exhibit both primary and secondary dormancy, allowing them to persist in soil for up to 3–6 years, depending on the environmental factors particularly moisture and temperature (Banting, 1962 and Hsiao, 1987). Secondary dormancy can occur when seeds are exposed to high moisture conditions. Wild oat has increased tremendously in the rainfed and irrigated areas of India as well as elsewhere in the world. It is a vigorously growing weed with a capability to attain greater plant height, establish well and develop extensive leaf area as well as more number of tillers when moisture and nutrients are not limiting. Wild oat is a serious economic threat to crop yields because of its competitiveness, staggered germination, crop mimicry and seeds shattering before crop maturity. The seeds have a high degree of phenotypic variation, substantial reproductive output, and the ability of seed to persist in the soil seed bank. Despite efforts to control these weeds through herbicide use, wild oat populations continue to persist, remaining the most abundant and competitive weeds in many areas (Qasem, 2007). These morphological and physiological characteristics of wild oat allow it to shade and suppress the growth of its neighboring plants to a level that causes yield reduction and poor quality of the produce.

Hence control of weeds is basic requirement and major component of management in the production systems (Young *et al*., 1996 and Norris, 1982). Different weed control strategies can be employed like preventive, cultural, mechanical, biological and chemical methods. However, conventional methods of weed control being weather dependent, laborious, time consuming and costly due to high cost of labour, power and mechanical means are also less efficient in controlling weeds compared to use of herbicides. Herbicide application is a preferred method for wild oat control due to lesser feasibility of mechanical or manual weeding in wheat because of its morphological similarity with wheat and narrow spacing. The use of herbicides will be the only acceptable method of weed control in the future (Young *et al*., 1996 and Singh, 2012, 2014).

The chemical control is of the recent origin that is being emphasized in modern agriculture. Taj *et al.* (1986) stated that herbicide treatments of crops allow economic weed control and provide cost-effective increase in agricultural productivity. Although herbicide currently in use combines a high degree of effectiveness with favorable production costs, non-toxicity and rapid biodegradation however some issues of herbicide selectivity and developing into herbicide resistance are causes of concern. Under such conditions it is important to find out the economic feasibility of wheat cultivation with herbicides under different establishment methods to get more profit with the environment safety. It has been proved that continuous use of single herbicide leads to development of resistance. Herbicides such as pinoxaden and clodinafop have shown high efficiency against grasses in wheat. But to control mixed population of weeds and also to avoid herbicides resistance by continuous use of single herbicide, compatible mixtures, crop and herbicide rotation can be employed to widen the spectrum of weed control (Singh, 2007 and Yaduraju, 2012).

Farmers are becoming increasingly interested in more comprehensive weed management programs that would lower weed populations over time and reduce their dependence on herbicides. Managing increased competitive ability of crops with weeds is an important means of achieving that goal (Liebman *et al*., 2001 and Singh, 2007). The fertilization is an important agronomic strategy used extensively to increase crop yield. Nevertheless, although nutrients clearly promote crop growth, many studies have shown that, in some cases, fertilizers benefit weeds more than crops (Di Toamso, 1995). Manipulation of crop fertilization is a promising cultural practice to reduce weed interference in crop (Gill *et al.*, 1997). The greatest competition among plants is usually for nutrients, and nitrogen (N) is the major nutrient input that farmers utilize to increase crop yield (Raun and Johnson, 1999). But it is not always recognized that altered soil nitrogen (N) levels can affect weed demographic processes and crop–weed competitive interactions. Nitrogen fertilizer has been documented in breaking dormancy of certain weed species (Agenbag and Villiers, 2009) and thus may directly affect weed infestation densities. Many weeds are high consumers of N (Hewson and Roberts, 1973 and Qasem, 1992) and therefore are capable of reducing available

N for crop growth. Not only weeds reduce the amount of N available to crops, but also growth of many weed species is enhanced by higher soil nutrient levels (Morales-Payan *et al*., 1998 and Supasilapa *et al*., 1992). Carlson and Hill in 1986 found that the addition of N fertilizer to wild oat-infested wheat increased the density of wild oat panicles without increasing crop yield. Indeed, in a controlled environment study, shoot and root growth of many agricultural weeds was found to be more responsive to N than that of wheat or canola (*Brassica napus* L.) (Blackshaw *et al*., 2003). This can lead to a worst case scenario where fertilizers increases the competitive ability of weeds more than that of the crop, and crop yield remains unchanged or decreases (Dhima and Eleftherohorinos, 2001 and Supasilapa *et al*., 1992).

Alex (1970) attempted to quantify damage caused by wild oat through yield loss but they did not assess the impact of the wild oat on the growth of the crop. In view of the importance of the wheat and wild oat competition, wild oat management with herbicide alone or compatible mixtures with variable levels of fertilizers were left as un-focused area in weed management. Information on fertilizer effects on crop–weed competitive interactions might aid in developing improved weed management programs. To manage the dynamic and complex weed flora in wheat there is need to evaluate different herbicides and their compatible mixtures to have a broad spectrum weed control. Considering all the constraints this research study on the effect of fertilizer levels and herbicides on wild oat management in wheat was conducted with the following objectives:

- Effect of fertilizer levels and herbicides on growth, yield and nutrient uptake by wheat
- Effect of fertilizer levels and herbicides on wild oat management
- To work out the economics of different treatments

CHAPTER-II

REVIEW OF LITERATURE

Wild oat is the most prevalent winter annual grass in wheat fields of northern India and worldwide (Singh *et al.*, 1995). It germinates along with wheat, grows quickly, establishes a deep and extensive root system and responds dramatically well to the higher levels of nitrogen and considered as the 13th most important weed worldwide and the most competitive weed in agricultural crops including wheat, all over India (Khan *et al*., 2006). Wild oat is a serious economic threat to crop yields because of its competitiveness, staggered germination, crop mimicry and seeds shattering before crop maturity. The seeds have a high degree of phenotypic variation, substantial reproductive output, and the ability of seed to persist in the soil seed bank. Despite efforts to control this weed through herbicide use, wild oat populations continue to persist, remaining the most abundant and competitive weeds in many areas (Qasem, 2007). These morphological and physiological characteristics of wild oat allow it to shade and suppress the growth of its neighbours to a level that causes yield reduction and poor quality of the produce. Continuous use of herbicides for managing the menace of *Avena ludoviciana* creates problems like shift in weed flora and evolution of herbicide-resistant weeds. A brief resume of research work carried out at different locations in India and abroad pertaining to different aspects relevant to present investigation has been reviewed and presented in this chapter, under the following headings:

2.1 Weed flora in wheat

2.2 Abundance and losses due to weeds

2.3 Effect of fertilization on wild oat and wheat

2.4 Effect of fertilization on yield and economics of wheat

2.5 Effect of hand weeding and herbicides on weed control in wheat

2.5.1 Effect of hand weeding on performance of wheat

2.5.2 Effect of pinoxaden on performance of wheat

2.5.3 Effect of clodinafop on performance of wheat

2.5.4 Effect of sulfosulfuron on performance of wheat

2.5.5 Effect of pendimethalin and metribuzin on performance of wheat

2.1 Weed flora in wheat

The extent of losses caused by weeds in wheat depends on the weed species, their abundance, crop management practices and environmental factors. The predominant weeds associated with wheat are *A. ludoviciana* Durieu, *Phalaris minor* Retz., *Polypogon monspeliensis* Desf., *Poa annua* L., *Rumex dentatus* L., *Chenopodium album* L., *Melilotus alba* Lamk, *Melilotus indicus* L., *Medicago denticulata* Willd, *Coronopus didymus* L., *Anagallis arvensis* L., *Lathyrus aphaca* L., *Convolvulus arvensis* L., *Vicia sativa* L., *Malva parviflora* L., *Circium arvense* L., *Polygonum plebejum* R. Br. and *Spergula arvensis* L. (Singh *et al*., 1995; Brar and Walia, 2007; Yadav *et al*., 2009; Punia *et al*., 2017).

2.2 Abundance and losses due to weeds

Major weeds that are competitive with wheat crop in North India, are *A. ludoviciana, Phalaris minor, Poa annua, Medicago denticulata, Convolvulus arvensis, Chenopodium album, Fumaria indica, Carthamus oxycantha, Galium aparine* and *Euphorbia helioscopia* (Hassan *et al.*, 2003). Weeds have a direct impact on wheat productivity and profitability by enhancing costs of labour, chemicals and other management inputs. Weeds also impact wheat production indirectly by competing with crop for resources, harboring other pests, interfering with water management and consequently, reducing the grain yield and quality (Zimdahl, 2013). Wheat is infested by multifarious weed flora comprising both grassy as well as broad leaved weeds may lead to reduction in grain yield to the tune of 29-66 per cent depending upon their intensity in field (Singh *et al.*, 2005; Sinha and Singh, 2005; Yadav *et al.*, 2006; Singh *et al.*, 2012). Uncontrolled growth of weeds on an average removed 20.9 kg N, 3.1 kg P and 26.9 kg K ha^{-1}. Kumar *et al*. (2013) estimated that with increase in weed biomass by 1 g m^{-2}, the wheat yield reduced by 41.6 kg ha^{-1}. An infestation of wild oat as small as 20 plants m^2 can cause a yield loss of 10 to 55 % in a wheat crop (Anderson, 2003).

Wild oat (*Avena ludoviciana*) and little seed canary grass (*Phalaris minor*) are the two most troublesome winter season grassy weeds reducing the yields of wheat (*Triticum aestivum* L.) crop in rice-wheat system of Indo-Gangetic plains (Brar *et al*., 2002). Yield losses in wheat due to uncontrolled weeds are higher as compared to other cropping systems (Singh *et al*., 2005). In a recent survey of wheat, weeds have high abundance but less diversity, with a clear dominance of grassy weeds such as *Avena ludoviciana* Durieu and *Phalaris minor* Retz (Punia *et al*., 2017). Among all weeds, *Avena ludoviciana* and *Phalaris minor* are the two most important grassy weeds of wheat, which are highly competitive and causes significant yield reductions in the range of 25-80 per cent depending on the severity of infestation (Singh *et al*., 1995; Chhokar and Malik, 2002). These weeds resemble wheat so closely that hand-weeding at the critical seedling stage is extremely difficult. A single plant of grassy weeds may produce as many as 1,100 seeds and 150 plants m^{-2} will reduce the wheat yield by 30 % (Wilson and Peters, 2014 and Sharma *et al.*, 2016). The loss due to *A. ludoviciana* may range from 30-80 per cent (Sharma *et al.* 2016 and Rana *et al*. 2016). The threatening problem of the same weed in Northern states (Haryana, Punjab and U.P) has been reported by early workers (Malik and Singh, 1995). *A. ludoviciana* is the most competitive weed in agricultural crops including wheat (Meena, 2014). Wild oat is a very troublesome weed in non-paddy rotations in light to medium textured soils and 30 plants m^{-2} can cause nearly 50 % yield losses in wheat (Walia and Brar 2001; Rana *et al*. 2016).

2.3 Effect of fertilization on wild oat and wheat

Nutrients are one of the most important factors for growth and development of plants and most limiting factors in crop production particularly in irrigated cereal based cropping systems. Blanket recommendation, most prevailing nutrient management strategy in India could not help in increasing the nutrient use efficiency beyond a limit (Singh, 2008); because temporal and spatial variability is not taken into account. Moreover, farmers have a tendency to apply nutrients in excess of the requirement of crop to avoid risk of deficiency. Overall farmers use about 10.5 % to 24.5 % higher N dose in rice–wheat cropping system of Haryana (Erenstein *et al.*, 2007 and Singh *et al.*, 2012) which lowers the N recovery efficiency. Yield losses are strongly influenced by the density of the infestation and the vigor of the weed, and are greatest when the wild oats emergence at the same time as the crop or early stages of the crop growth (Scursoni and Satorre. 2005; 2011). Nitrogen is a major nutrient required by crop plants and as well as weed plants too like *A. ludoviciana.* Weed competitiveness studies carried out by Babu and Jain in 2016 and reported that wheat was more competitive than *P. minor* at high N, but less competitive at low N. However, *A. ludoviciana* was more competitive than crop at both N levels.

Nitrogen management is the key approach in improving quality and productivity of wheat. Therefore, optimum use of nitrogen throughout the crop period is of vital importance to exploit the production potential of crop. Weeds have naturally good competitive ability; use more water and nutrients as compared to the crop plants (Kaur *et al.,* 2012). Nutrient application to crop to improve the productivity does not always benefits the wheat (Dawlatzai *et al.,* 2016 and Verma *et al.,* 2016). Different N levels increased seedling emergence of wild oat between 25 and 35 per cent compared to the no- nitrogen treatments (Agenbag and Villiers 2009) and different nitrogen levels. Watkins (2011) reported that annual dressing of nitrogen fertilizer on winter cereals in wild oat infested area led to an increase in the population of weed. In an another research on wild oat and wheat Henson and Jordan 2012 and Wilson and Peters 2014 found similar results like wild oat competition caused larger reduction in dry weight and grain yield, and smaller reduction in per cent nitrogen and also, the wild oat competition reduced the effectiveness of nitrate in increasing plant weight, grain yield, and whole plant per cent nitrogen of wheat. Malik *et al.* (2013) carried out study on evolving strategies for herbicide use in wheat using integrated weed management and their study indicated that, 30 kg N ha^{-1} with 400 wild oat plants m^{-2}, the dry weight of the wild oat was 480 g m^{-2} compared to 570, 606 and 696 g m^{-2}, for 60, 120 and 180 kg N ha^{-1}, respectively; also reported that with the higher dosage of N fertilizers, the dry weight of wild oat also increased and yield of wheat is declined hence it was concluded from their study that fertigation above the recommended dose of fertilizer will possibly add up to the weed biomass. However, Banisaeidi *et al*. (2014) conducted a study to determine the effect of various plant densities and nitrogen fertilizer on spring wheat and wild oat competitiveness and they found that increased wild oat density with nitrogen fertilizer can improve spring wild oat competitiveness with enhanced yield loss in wheat and improved seed production and biomass of wild oat. Whereas, Ross (2015) reported that wild oat competitiveness in wheat was significantly greater in the presence of nitrogen fertilizer. While Allyn and John (2016) stated that wild oat competition increased with increased nutrient availability.

Morishita and Donald (2014) observed that wild oat interference reduced biomass of crop, the number of tiller $plant^{-1}$, tiller heads per unit area, and also reduced total water and turgor potential in crop at the boot stage of growth. The effect of nitrogen rate on the relative biomass showed nitrogen application reduced relative wheat biomass while relative wild oat biomass was increased indicating that wild oat competitive effects on wheat may increase with N supply in both field and screen house. Similar observations were made by Khan *et al.* (2015) and he reported that a single plant of wild oats inflicted 10 % decrease in tillers $plant^{-1}$of wheat. These results indicate that wheat as well as wild oat mutually inhibits their growth in mixture, but the inhibition is significantly more by wild oat to the wheat than the wheat to wild oat. In another experiment Babu and Vikas (2016) found that total dry weight of wheat was significantly lower in mixture (wheat and wild oat) than in monoculture (only wheat). *A. ludoviciana* was more competitive than crop at lower (20 kg ha^{-1}) and higher (120 kg ha^{-1}) N levels, leaf area index and leaf chlorophyll content of both wheat and weed were at par in mixture at high N and in monoculture at low N, indicating a higher competitiveness of *A. ludoviciana*; evident from the study of Muhammadi *et al.* (2016) wherein they reported the maximum plant height and tillers of wild oat (128.82 cm and 107) were obtained at 150 kg N ha^{-1} and least with RDF. In a study conducted on effect of wild oat on wheat cultivars with short and long duration in both field and screen house, Ponce (2016) reported that the wheat cultivar with the longest cycle were the most affected plants by wild oat competition as regards to height, number of tillers and leaf area index. Wild oat competition with wheat plants was greater than the competition among wheat plants themselves with higher levels of fertilizers.

2.4 Effect of fertilization on yield and economics of wheat

In a study conducted to quantify the competition between wheat and wild oats (field and screen house); Hassan and Khan (2007) recorded grain size as low as 12 % under 50 wild oats plants m^{-2} as compared to monoculture of wheat. The adverse effect of wild oats on yield components reflected on the grain yield. More than 50 % reduction in yield was noticed and B:C ratio at the highest density of wild oats was negative as compared to monoculture of wheat. However, Khan *et al.* (2009) reported that less than 1 wild oat plant m^{-2} inflicted 1 per cent reduction in wheat yield, while 30 per cent reduction in yield was predicted with the infestation of 15, 16 and 27 plants m^{-2} under 75, 100 and 125 kg ha^{-1} N respectively. They also observed that wild oat infestation caused reduction in grain protein content related with the nitrogen dosage of the crop and found that highest uptake of nutrients through wild oat in higher fertilized plots. The grain yield of wheat and its dry matter often influenced by the level of N application as indicated by the work of Telavat *et al.* (2010); wherein they reported that grain yield and dry matter of wheat significantly decreased with increasing nitrogen at lower herbicide levels. However, the application of higher doses of herbicide at higher nitrogen levels reduced grain yield and dry matter of wild oat. Their results also reflected that at lower nitrogen levels there was no significant difference between herbicide doses and increasing nitrogen without increasing herbicide dose or at lower level of herbicide doses also significantly increased dry matter of wild oat in screen house study as well as in field study. Whereas, Balyan (2011) studied competitive ability of winter wheat cultivars with wild oat and they reported that wild oat reduced wheat grain yield by 17 to 62 per cent depending on the cultivar. They also observed wheat dry matter accumulation and grain yields were negatively correlated with wild oat dry matter and nutrient uptake by wild oat and wheat. Scursoni and Satorre (2005, 2011) reported yield loss was almost 25 per cent when 70 wild oat plants m^{-2} were established.

Presence of 15 plants m^{-2} of *A ludoviciana* resulted in significant decrease (10 – 14 per cent) in grain yield of wheat (Kaur *et al.*, 2013). Reduction in yield was mainly caused by the reduction in effective tillers, number of grains per spike and test weight as well as poor nutrient uptake by the crop. Saeed *et al*. (2013) found that wheat yield and yield components were higher when nitrogen and sulfur fertilizers were applied in split doses and they concluded that N and S spray at the rate of 10-15 per cent during different growth stages improved the grain yield and yield components and contributed significantly to increased production where there is no wild oat population and the opposite trend was observed with wheat and wild oat mixed population. Martin. and Field (2014), reported that wild oat was more competitive than wheat, as shown by its aggressively relative to wheat relative yields; shoot dry weight and other yield attributes when excess nutrients were present in soil. Nutrient uptake was higher in wild oat rather than wheat with higher levels of fertilizers. Pot and field experiments conducted by Zamani (2015) and he reveled that wild oat caused reductions in wheat yield and yield attributes like grains per panicle, panicle length, test weight of wheat and this reduction increased with increasing densities of wild oat with increased fertilizer dosages, leading to poor returns and lower B:C for the farmers with higher dosages of fertilizers. Harry, and James, (2015) found that wheat grain yield in wild oat-infested plots generally declined with fertilization while the density of wild oat panicles increased and recorded lower B:C (0.88) with higher levels of fertilizers. Apparently, in competition with wheat, wild oat was better able to utilize the added nitrogen and thus gained a competitive advantage over the wheat and better nutrient uptake was recorded with wild oat. The increased competitiveness of wild oat resulted in reduced crop yields. Jafar, P. and Abdollah, (2015) conducted research to quantify the effect of nitrogen fertilizer on wheat and wild oat competition. They found that there was significant effect of nitrogen application on estimated maximum wheat yield loss. The application of nitrogen 150 kg ha^{-1} before crop seeding resulted in a greater higher competitive ability of wild oat and lower B:C than 100 and 75 kg N ha^{-1}.

Working on effect of wild oat density on wheat yield, Woldesenbet *et al.* (2016) reported the maximum values of all the growth and yield parameters in the lower wild oat density as compared to higher wild oats density and hence they concluded that wheat yield and yield components were greatly affected by wild oat densities at the same time higher nutrient uptake by wild oat also observed with higher density of wild oat with higher levels of fertilizers. Ahmedvand *et al.* (2016) found that dry weight, grain yield, and number of tillers and grains per spike of wheat significantly declined as the plant density of wild oat increased with fertilization. Poor uptake of nutrients by crop because of extreme competition of wild oat was the reason behind poor crop growth and lower yields and negative B:C ratio. Torner *et al.* (2016) found 10 % reduction in yield with wild oat densities ranging from 20-80 panicles m^{-2} at recommended dose of fertilizer and yield losses reached 50 %, with densities of more than

300 panicles m^{-2} when the fertilizer dosage was more than the recommended dose of fertilizer. Hence, weed management plays a vital role in boosting up wheat production. Nitrogen fertilization in excess enhances the weed population and growth and may reduce the nitrogen use efficiency by the crop. James *et al.* (2016) observed decline in wheat grain yield in wild oat-infested plots with fertilization when the density of wild oat panicles increased. Apparently, in competition with wheat, wild oat was better able to utilize the added nitrogen and thus gained a competitive advantage over the wheat. The increased competitiveness of wild oat resulted in reduced crop yields and finally negative B:C.

Nutrient synergy and herbicide dose interaction is the new solution for better control of weeds in future. The problem with the higher dose of nutrients for lower efficacy of herbicides was not focused properly in the research but needs to be flourished to give answers for the future questions of weed management. Nitrogen is the nutrient that most often limits crop production. Among major cereals, wheat requires 1 kg of N to produce 44 kg of wheat (Pathak *et al*., 2003). Generally, more than 50 per cent of the N applied is not assimilated by plants (Dobermann and Cassman, 2004). Kim *et al*. (2006) reported that the significant interaction between herbicide and nitrogen where increased nitrogen found to reduces the performance of herbicide, and N-scheduling not only influences the crop growth but also influences weed density and biomass. However, information in this regard is lacking. So, there is a greater need for new formulated herbicides with nitrogen rates and time of application to make out the effect of treatments on growth and yield of wheat. Herbicide application at seedling stage of crop growth in the absence of DAP was more effective in reducing weeds density and dry weight. Crop height, effective tillers, biological yield, grain and straw yield, seed and harvest index increased due to sequential application of clodinafop and isoproturon during seedling stage in the absence of DAP compared to weedy check and elongation stage in the absence of DAP. Need more research on the interaction effect of nutrients and herbicides to avoid the risk of resistance in weeds and other serious problems of weed management in wheat.

2.5 Effect of hand weeding and herbicides on weed control in wheat

Since removing weeds by physical methods is laborious, tiresome and expensive due to increasing cost of labour, draft animals and implements and weeds cannot effectively be managed merely due to crop mimicry, therefore, the use of herbicides for weed control has become necessary (Marwat *et al.,* 2008 and Singh, 2006). However, the choice of most appropriate herbicide, proper time of application and proper dose is an important consideration for lucrative returns (Abbas *et al.*, 2009 and Khali *et al.*, 2012). Application of herbicides decreased dry weight of weeds significantly compared to non-treated plots and increased yield components and grain yield (Ashrafi *et al.,* 2009 and Bibi *et al.,* 2008). Therefore use of herbicides is an excellent option for efficient weed control. Herbicides have been the most dominant technological tool in wheat production in India and have contributed to substantial increase in crop yields (Singh, 2007). However, over reliance on herbicides has ruined their success due to development of herbicide-resistant weeds in wheat to achieve optimum yields. Herbicides are still pivotal for weed management in modern cropping systems. However, considering the dearth of new herbicides with novel mode of actions it becomes imperative to enhance the life span of exisiting herbicides and this can be done by employing these herbicides as mixtures, in sequences or rotations and such measures may delay herbicide resistance although these are unlikely to prevent resistance evolution. Long-term management of resistant weeds will require the integration of herbicides with non-chemical weed control tactics so as to bring diversity in weed control which would minimize selection for herbicide resistance traits (Om *et al*., 2004; Singh, 2006; Singh, 2014 and Beckie and Harker, 2017).

Sole reliance on POE herbicides in the absence of other non-chemical measures has exploded herbicide resistance in weeds in wheat in India with new resistant species confirmed every few years. *A. ludoviciana* and *P. minor* are the most ubiquitous weeds of wheat which have evolved multiple-resistance against different MOAs (C2/7, A/1 and B/2) and no registered herbicide provides effective control of these populations. At present, *P. minor* and *A. ludoviciana* are effectively controlled neither at double the application rates nor with sequential/mixed use of several POE herbicides, thus, denting the wheat productivity and profitability. Recently, *A. ludoviciana* to ACCase inhibitors and *C. album* to sulfonylureas has also started defying concert (Singh, 2016b; Chhokar *et al*., 2017 and Singh *et al*., 2017). Moreover, there are no new mechanisms of action (MoA) on the horizon and the last MoA was developed more than 30 years ago.

2.5.1 Effect of hand weeding on performance of wheat

Hand weeding is an important weed control measure, because it removes complete weed flora from the cropping area. It helps crop to get better aeration and good establishment because of no competition by weeds and hence results in the higher productivity. However, conventional methods of weed control being weather dependent, laborious, time consuming and costly due to high cost of labour, power and mechanical means are less efficient in controlling weeds compared to use of herbicides. Crop mimicry of weeds makes hand weeding less effective and unproductive with respect to economics. Surin *et al.* (2015)

reported that hand weeding at 25 and 50 DAS in wheat recorded 31.3 per cent higher productive tillers m^{-2}, 5.3 per cent higher spike length thereby resulting in 35.8 and 38.6 per cent higher grain and straw yields as compared to weedy check. Pisal and Sagarka (2015) noted superiority of weed free treatment in wheat over 2 hand weedings at 20 and 40 DAS r for improving growth and yield attributes and grain yield over weedy. Plant height, tiller density and dry matter production were increased significantly with two manual weeding in comparison to weedy check was (Pradhan and Chakraborti, 2015). In a field experiment, Meena and Singh (2016) found that hand weeding increased the plant height and dry matter of wheat in comparison to metsulfuron methyl at 4 g/ha, sulfosulfuron 30 g/ha and 2,4-D Na salt at 625 g/ha respectively. Hand weeding also resulted in 100 per cent control of weeds and also enhanced the yield attributes *viz.*, ear heads m^{-2}, test weight and yield. Tesfay *et al*. (2016) reported the highest straw yield, harvest index and N uptake in hand weeding followed by isoproturon 1.50 kg ha^{-1}. Hand weeding offered better WCE than all herbicides but the B:C was lower because of the cost of the labour and time invested (Rana *et al.*, 2016; Ortrud *et al*., 2017).

2.5.2 Effect of pinoxaden on performance of wheat

Herbicides are the foundation of weed control in crop production systems across the globe. Herbicides control weeds effectively, enhance crop yield and profit. Increased use of herbicides has greatly impacted on world agriculture. Pinoxaden Inhibits the enzyme Acetyl-Coenzyme A- Carboxylase (ACCase) and thus inhibits the production of fatty acids and as a final consequence interrupts the formation of bio membranes and hence effective against grassy weed control in wheat. Used Post-emergence, grass selective, foliar absorbed and translocated herbicides are used for controlling annual grasses. The post emergence application of pinoxaden 50 g/ha, sulfosulfuron 25 g/ha, and mesosulfuron + iodosulfuron 12 g/ha reduces wild oat population and dry matter accumulation of grass weeds (Saini *et al.*, 2012). Similar observations were also made by Shoeran *et al.* (2013), wherein they reported that application of pinoxaden proved significantly effective in reducing density and dry weight of weeds and gave 55-85 % control of broad-leaved and 100 per cent control of grassy weeds. Kumar *et al.* (2013) reported that sulfosulfuron 25 g/ha was found significantly superior to alone application of pinoxaden 40 g/ha with wheat grain yield, which was evident from the higher weed control efficiency as compared to clodinafop 60 g/ha and least was observed under metribuzin 210 g/ha. Punia *et al.* (2014) reported that post-emergence use of pinoxaden at 50 g/ha (35 DAS) with sequential use carfentrazone at 25 g/ha (42 DAS) with 1 per cent ammonium sulphate provided complete control grass and broadleaf weeds without any phytotoxic effect on wheat crop. Katara *et al.* (2015) also reported that pinoxaden *fb* metsulfuron-methyl resulted in significantly lower total weed dry weight over rest of the herbicidal treatments and also resulted in significantly higher wheat dry matter accumulation over rest of the treatments. Anders *et al.* (2018) reported that the best control over the *A ludoviciana* with the pinoxaden resulted in better growth and yield parameters of wheat.

Anil *et al*. (2016) worked on bio efficacy of pinoxaden applied to wheat crop at 35, 40, 80 and 160 g ha^{-1} and found that application of pinoxaden at 40 g ha^{-1} mixed with surfactant, (A12127 R) significantly controlled grass weeds, especially little seed canary grass and normal wild oats in wheat as evident from the lowest number of weeds m^{-2} and weed biomass. No phytotoxic symptoms were observed in wheat crop treated up to 160 g ha^{-1}. When paddy was grown on the same piece of land, there was no adverse effect on the crop stand. Mahmood *et al.* (2017) indicated that all treatments of herbicide significantly controled the weeds causing significant reduction in weed mass and also improved the grain yield in comparison with the check and the best herbicide out of all herbicides used was pinoxaden.

Pinoxaden 50 g ha^{-1} reduced *P. minor* and *A. ludoviciana* weeds significantly whereas, clodinafop 60 g ha^{-1} and sulfosulfuron 24.5 g ha^{-1} were at par with each other but significantly inferior to pinoxaden but significantly superior over pendimethalin 750 g/ha, isoproturon 937 g ha^{-1}. Numbers of effective tillers m^{-2} were higher among pinoxaden, clodinafop and sulfosulfuron treatments than the isoproturon, pendimethalin and unweeded check (Balakaran, and Dhaliwal 2016). Bhagat *et al.* (2017) reported that the increase in grain yield due to application of pinoxaden @ 40 g ha^{-1} *fb* metsulfuron @ 4 g ha^{-1} was 22.5 per cent over weedy check. The similar observations on efficacy of pinoxaden in controlling the weeds with enhanced yield was also made by Rana *et al.* (2016); wherein they reported that sequential application of pinoxaden *fb* metsulfuron methyl (40 fb 4 g ha^{-1}) resulted in significantly higher grain yield with increased net returns (47489 ha^{-1}) and net returns per rupee invested (1.97). Pinoxaden *fb* metsulfuron methyl (40 g ha^{-1} *fb* 4 g ha^{-1}) increased NPK uptake by wheat to 88.5, 19.2 and 49.6 kg ha^{-1} from 47.5, 9.1 and 29.2 kg ha^{-1} respectively, obtained under weedy check as reported by Sharma *et al*. (2016). Ortrud *et al*. (2017) observed influence of pinoxaden on *A. fatua* panicle production significantly differed between the other chemicals.

2.5.3 Effect of clodinafop on performance of wheat

Clodinafop is a post-emergence, systemic grass herbicide inhibits lipid biosynthesis (ACCase). Clodinafop is used for post emergence control of annual grasses, including *Avena*, *Lolium*, *Phalaris* and *Alopecurus* in cereals. Clodinafop effects meristematic tissue in wild oat, and the efficacies of clodinafop considerably lower than the pinoxaden. Singh *et al*. (2013) reported that tank-mix application of metsulfuron-methyl @ 4 g a.i ha^{-1} with clodinafop and sulfosulfuron at 35 days after sowing significantly reduced the weed density and resulted in 26.2 per cent and 18.9 per cent higher grain yield respectively with higher net returns, benefit: cost ratio over farmer's practice. Post-emergence application of fenoxaprop 100 g and clodinafop 60 g ha^{-1} in late sown wheat eliminated crop weed competition at tillering and grand growth period which ultimately provided congenial conditions to crop for better harnessing of available crop growth resources and produced profitable grain yields were reported by Singh *et al.* (2014). Sidhu *et al.* (2014) also found that application of clodinafop (60 g ha^{-1}) followed by carfentrazone-ethyl (20 g ha^{-1}) resulted in significantly higher grain yield (4.56 and 4.69 t/ha). Kaur *et al.* (2015) reported that ready-mix of clodinafop+ metsulfuron at 75 g ha^{-1} + 0.2 per cent surfactant effectively controlled grass and broadleaf weeds and recorded similar wheat grain yield to sequential application of clodinafop 60 g ha^{-1} and metsulfuron 4 g ha^{-1} and weed free without any phytotoxicity symptoms on the crop.

Abbas *et al*. (2016) reported that herbicide mixture combinations (clodinafop + metribuzin, pinoxaden + sulfosulfuron, pinoxaden + metribuzin and sulfosulfuron + clodinafop) having 75 per cent lethal dose of each mixture component provided best control against grassy weeds of wheat. Mixtures with 50 per cent lethal dose of each herbicide also provided more than 80 per cent control of *A. ludoviciana*. In another experiment Yadav *et al*. (2016) documented that the tank-mix application of clodinafop with many other herbicides at 35 DAS provided 90-100 per cent control of *P. minor* and *A. ludoviciana* along with broadleaf weeds in wheat. Kumar *et al*. (2013) found that clodinafop 60 g ha^{-1} + metribuzin 122.5 g ha^{-1} resulted in highest weed control efficiency, crop resistance index and efficiency index. It gave lowest weed persistence index, weed index, and resulted in highest net return due to weed control. Jain *et al.* (2016) observed that the application of clodinafop *fb* 2,4-D brought significantly higher weed control efficiency over isoproturon and clodinafop alone and lowest total weed density (7.8 m^{-2}) and dry weight (5.1 g m^{-2}) which resulted in 4.9, 5.8 and 18.4 per cent higher grain yield over isoproturon, clodinafop and weedy check, respectively. In another study, combinations of herbicides within the same group *i.e.* ACCase inhibitor with ACCase inhibitor and ALS inhibitor with ALS inhibitor were compatible and resulted in very effective control of *A. ludoviciana* and consequently yields of wheat. The plant growth and growth parameters (plant height, leaf area, dry matter and WCE and weed index) were better with the application of clodinafop 60 g ha^{-1} (Mishra 2006; Bibi *et al.,* 2008; Chaudhary *et al*., 2013; Paighan *et al.,* 2015). Clodinafop improves the spike length, spike length, grains per panicle, and grain yield and straw yield by reducing weeds when compared with weedy and other treatments (Khan *et al*., 2003; Hassan *et al*., 2005; Hussian *et al*., 2013: Hooda *et al*. 2015).

2.5.4 Effect of sulfosulfuron on performance of wheat

Sulfosulfuron is used for the control of annual broad leaf and grass weeds in cereals. It kills the wild oat by inhibiting acetolactate synthase (ALS) in plant system. The application of sulfosulfuron (25 g ha^{-1}) resulted in lower weed density and dry weight of weeds with enhanced higher weed suppression efficiency (83.43 per cent) and higher grain yield by (Singh *et al.,* 2010). Bharat *et al.* (2012) also found that application of sulfosulfuron (50 g ha^{-1}) reduced weed population and biomass significantly and thereby caused increase in crop growth and grain yield of wheat. Dev *et al.* (2014) found that minimum weed density and dry matter and increase in the yield attributes and yield, gross returns, net returns and B: C ratio with sulfosulfuron 25 g ha^{-1}.

Chhokar *et al.* (2013) studied the efficacy of sulfosulfuron and reported that its efficacy was not affected by tank mixture with dicamba. As a result this mixture (sulfosulfuron + dicamba 25 + 120 g ha^{-1}) had the highest wheat grain yield (4.99 t ha^{-1}). The dry weight of *A. ludoviciana* and *P. minor* was reduced by 97.3 per cent and 88.94 per cent with clodinafop 60 g ha^{-1} alone and in tank mix combination with dicamba 240 g ha^{-1}. Under pot culture experiment, they also found that in, *A. ludoviciana and P. minor* biomass reduction with clodinafop 30 and 60 g ha^{-1} was reduced by 84.8, 99.6 and 89.2, 94.3 per cent, respectively. The work of Singh *et al.* (2013) revealed that post-emergence application of carfentrazone + sulfosulfuron with surfactant at 45 g ha^{-1} found to have minimum density and dry weight of weeds and significantly the higher grain yield over its rate of 36 g ha^{-1}. Whereas, Jat *et al*. (2014) reported that combination of metsulfuron + sulfosulfuron (4+25 g ha^{-1}) reduced weed population and biomass significantly and thereby caused increase in plant height, crop dry matter and grain yield (5.22 tonnes ha^{-1}). The highest net returns (Rs. 52,400) and B:C (3.78) were also recorded with tank-mix application of sulfosulfuron + metsulfuron.

While evaluating the different weed control treatments, Vyavahare and Bhilare (2015) reported that, application of sulfosulfuron 16.5 g ha^{-1} + 2,4-D 563 g ha^{-1} registered significantly lower weed population (7.6 m^2), dry matter of weeds (3.1 g m^{-2}) and significantly more weed control efficiency of 81.27 % than rest of the treatments. Singh *et al.* (2015) obtained maximum grain yield in treatment metribuzin 42 % + clodinafop-propargyl at 600 g ha^{-1} due to effective control of grassy and broad-leaf weeds in wheat. Singh *et al.* (2015) reported that post-emergence application of sulfosulfuron + metsulfuron (32 g ha^{-1})

with higher rates 160 kg N ha^{-1} applied in split doses at different stages of growth performed significantly with respect to reduction in density and biomass of weeds and enhanced the production of grain yield of wheat. Scheduling of nitrogen enhanced the nitrogen uptake efficiency and total nutrient uptake by crop whereas application of higher dosage reduces the efficacy of herbicide. Likewise, Shyam *et al.* (2016) reported that sulfosulfuron at 33.3 g ha^{-1} recorded significantly lower weed intensity and biomass, higher weed control efficiency. The maximum nutrient removal by wheat crop and response over weedy check towards grain yield of wheat (129.6 per cent) were with weed free treatment followed by sulfosulfuron at 33.3 g ha^{-1}. The maximum net return (Rs. 31,475 t ha^{-1}) and B:C ratio by wheat cultivation and (1:1.80) were obtained with sulfosulfuron at 33.3 g ha^{-1}.

2.5.5 Effect of pendimethalin and metribuzin on performance of wheat

Metribuzin as Selective herbicide is used for pre and post-emergence control of broad leaf weeds and annual grasses. It acts by inhibiting photosystem II of photosynthesis by disrupting electron transfer. This results in death due to starvation in the target plant. But pendimethalin works with different mode of action *i.e.*, inhibition of mitosis and cell division and micro tubule assembly inhibition was the main mechanism and absorbed by roots mostly hence efficacy was poor compared with all other herbicides. Yadav *et al.* (2016) conducted study on response of wheat and associated weeds to irrigation schedule and pendimethalin. They found that pendimethalin @ 2.0 kg ha^{-1} pre emergence reduced the weed density and weed biomass significantly. The pre-emergence application of pendimethalin (1.5 kg ha^{-1}) reduced the density and dry matter accumulation by grassy weeds effectively and increased the wheat grain yield by 25 per cent over weedy check (Jat *et al.* 2013). Paighan *et al.* (2015) observed an average decrease in grain yield by 15.42 per cent due to season-long weed-crop competition. The best weed control efficiency in case of monocot (90.8 per cent) and dicot (82.8 per cent) was achieved with metsulfuron-methyl and metribuzin, respectively. Kaur *et al.* (2016) conducted a field experiment on bio-efficacy of two new brand formulations Penda 30 EC and Mark Pendi 30 EC for control of grass weeds in wheat. The tested new brand formulations of pendimethalin (Mark Pendi 30 EC and Penda 30 EC) were at par to earlier recommended brand (Stomp30 EC) with respect to weed population, dry matter accumulation and wheat grain yield. Chhokar *et al*., 2008 and Patro and ray 2016 found that sequential application of pendimethalin as pre-emergence followed by sulfosulfuron as post-emergence recorded the highest weed control efficiency (96 per cent) and wheat grain yield (4.8 t ha^{-1}) it was at par to pre-emergence pendimethalin + metribuzin, post-emergence pinoxaden + metsulfuron, mesosulfuron + iodosulfuron, sulfosulfuron + metsulfuron and two hand weeding. Pendimethalin + one hand weeding remarkably reduced the weed dry matter and resulted in increased weed control efficiency. Chopra and Chopra (2001) stated that pendimethalin alone or metribuzin alone cannot able to control weeds in wheat field effectively. The sequential application of both have some effect on WCE but not comparable with clodinafop, pinoxaden and sulfosulfuron (Wicks *et al*., 1987 and Kapil 2017). Herbicides controlled weeds much better in wheat compared with the weedy and in many cases they were at par relation (Bharat and Kachroo 2010 and Patro and ray 2016). Alone application of pendimethalin registered under lowest control of grass weeds in wheat.

CHAPTER–III

MATERIALS AND METHODS

The field and pot experiments under the investigation entitled, **“Effect of fertilizer levels and herbicides on wild oat management in wheat"** was carried out during *rabi* seasons of 2015-16 and 2016-17. The pot experiments were conducted in the screen house of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana) and field experiment was conducted at Weed Control Research area of Department of Agronomy, CCSHAU, Hisar. The details of materials used, methods followed and techniques adopted during the course of this investigation are described in this chapter.

3.1 Location of the experimental site

The experiment was conducted at Research Farm of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar located at 29^0 10' North latitude and 75^0 46' East longitude with an elevation of 215.2 m above mean sea level. Pot studies were conducted under controlled conditions in the screen house located in College of Agriculture CCSHAU, Hisar.

3.2 Weather conditions

The experimental site comes in the tract of semi-arid, continental and monsoonal and sub-tropical climate. Four seasons can be distinguished during the year: a dry summer from March to June, a warm and humid rainy season from July to September, a post monsoon warm season from October to November, and a severe to mild winter from December to February. A wide range of fluctuations is experienced for the mean maximum and minimum temperatures during both summer and winter.

Maximum temperature touches around 48° C during hot summer months of May and June, while during winter months of December and January the minimum temperature comes down to sub-zero. The average annual rainfall of the area is around 450 mm, 70-80 % of which is received during monsoon period *i.e.,* July to September and the rest is received in showers of cyclic rains during the winter and spring seasons. The pattern of monsoon shower is highly erratic in respect of its total amount, time of onset as well as distribution over the period of the rains. The mean relative humidity remains nearly constant at about 75 to 90 % from July to March, steadily decreases in April and remains around 40-50 % during hot summer months of May and June. The annual average relative humidity fluctuates around 76 and 39 % in the morning and evening, respectively. Average vapour pressure value comes to 8.5 mm in the morning and 26.0 mm in evening, which remains around 20-22 mm in the monsoon period and 7-12 mm during rest of the year. Annual average bright sunshine hours are 6.9. Annual average wind speed is 5.5 km hr^{-1}; highest (8-10 km h^{-1}) during May to July and least (2.5- 5.5 km h^{-1}) during October to March. The moisture adequacy index is > 0.5 during monsoon months while it is < 0.5 during the freezing winter season.

The actual mean weekly meteorological data during the crop seasons of *rabi* 2015-16 and 2016-17 recorded at observatory located at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar are given in Appendices I and II, Fig. 3.1a and 3.1b. The rainfall received during the *rabi* seasons of 2015-16 and 2016-17 was 30.5 and 48.7 mm, respectively. The mean weekly maximum temperature in *rabi* 2015-16 varied between 15.3 to 31.5° C and minimum between 3.5 to 15.3° C, while, their corresponding values in *rabi* 2016-17 were 16.9 to 37.2° C and 3.2 to 17.5° C. The mean weekly morning and evening relative humidity varied between 83 to 97 and 36 to 75 % respectively in *rabi* 2015-16 and between 59 to 100 and 16 to 81 % respectively in *rabi* 2016-17. During the *rabi* crop season daily sunshine hours ranged between 2.2 to 9.3 hours in 2015-16 and between 2.9 to 10.3 hours in 2016-17.

3.3 Soil analysis of the experimental field

The soils of Hisar are formed from Indo-Gangetic alluvium, which are very deep and sandy loam in texture and have some amount of calcium carbonate in the soil profile. Physico-chemical analysis of the soil was done by taking random soil samples from plough-layer (0-15 cm depth) of the field before layout of the experiment. The composite soil sample was analyzed for various physical and chemical properties. Soil samples collected after each harvest of the crop from each treatment were analyzed for various physical and chemical properties. The results are presented in Table 3.2

3.3.1 Mechanical analysis of soil

The mechanical analysis of the composite soil sample from experimental site was carried out by International Pipette method (Piper, 1966). The soil is categorized as sandy loam in texture on the basis of mechanical composition (Table: 3.1).

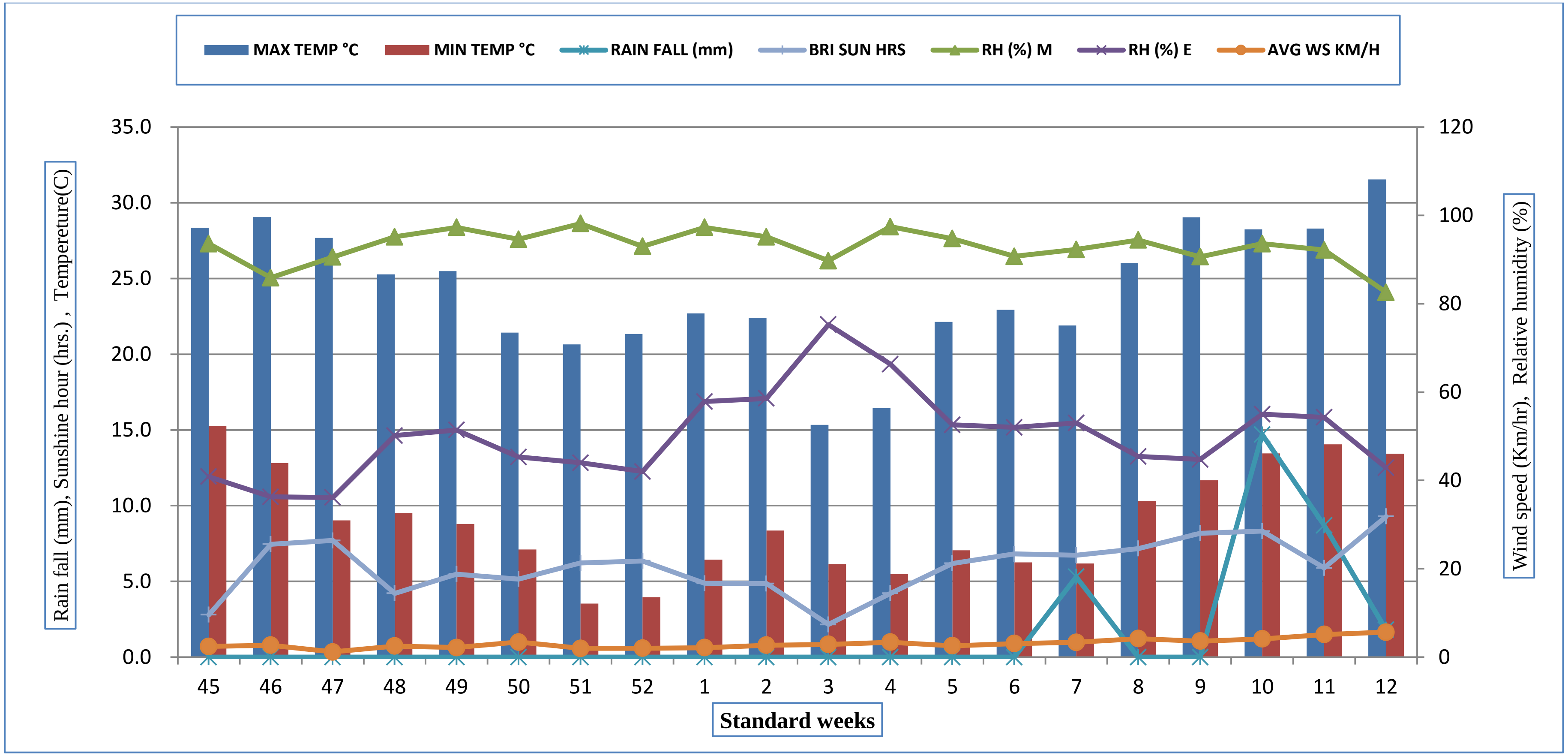


Fig. 1a : Mean weekly meteorological data during the crop growth period 2015-16 at CCSHAU, Hisar

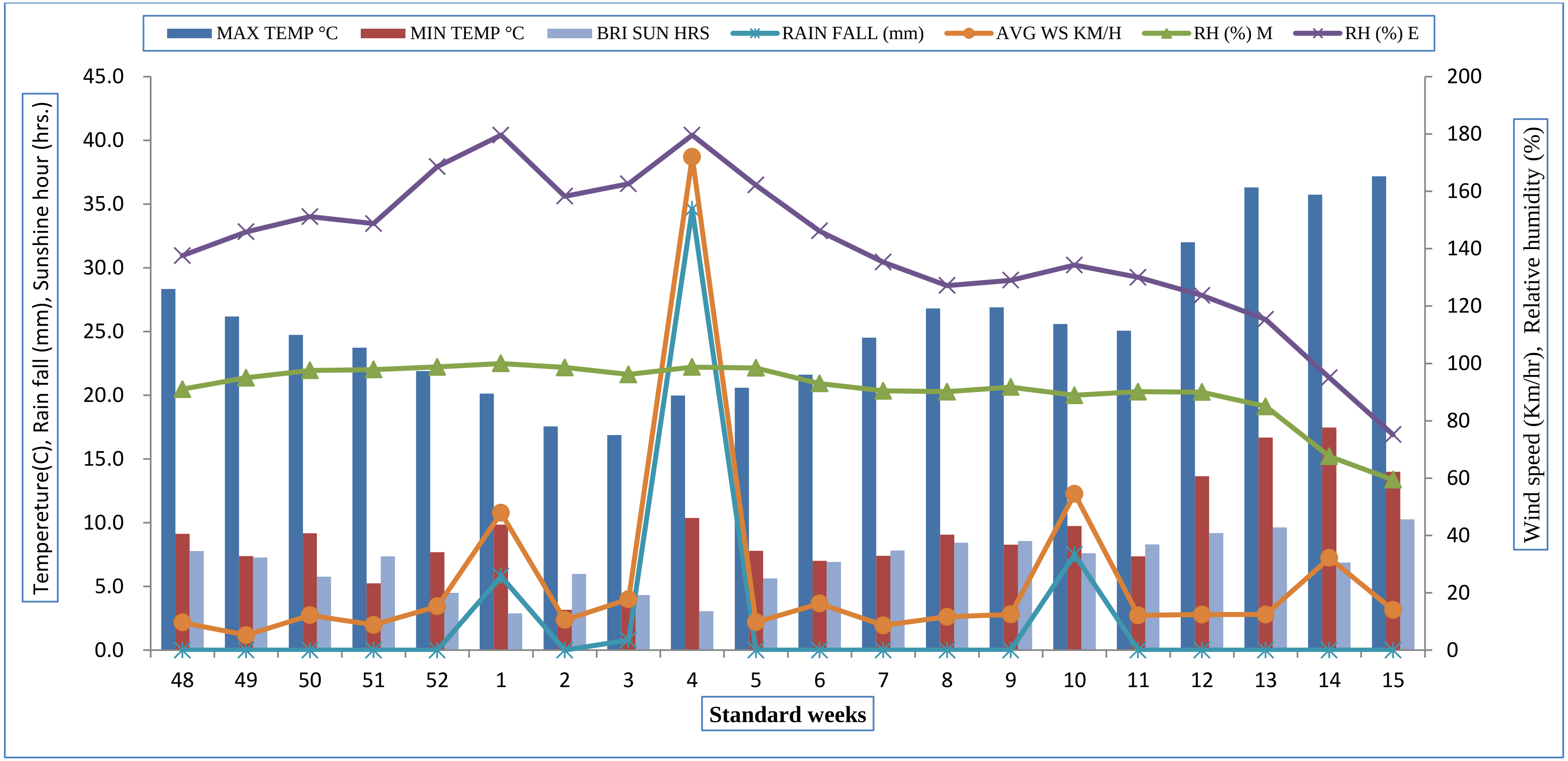


Fig. 1b : Mean weekly meteorological data during the crop growth period 2016-17 at CCS HAU, Hisar

Table 3.1: Physical properties of soil of experimental field

Component	Fraction	Method of Estimation
Sand Silt Clay Textural class	57.5 (%) 24.3 (%) 18.2 (%) Sandy loam	International pipette method (Piper, 1966)
Bulk density	1.42 (g cm^{-3})	Core sampling (Piper, 1966)
Infiltration rate	4.6 (mm hr^{-1})	Double ring infiltrometer
FC at -0.03 (MPa) PWP at -1.5 (MPa) Available water	20.5 (%) 6.1 (%) 14.4 (%)	Pressure membrane apparatus (Richards, 1954)

3.3.2 Chemical analysis of soil

The composite soil sample was analyzed for N, P, K, organic carbon, soil reaction and electrical conductivity (EC). The data regarding the different chemical properties of the soil presented in Table 3.2 indicate that the soil of the experimental field was slightly alkaline in reaction, medium in organic carbon and low in available nitrogen, high in available phosphorus and medium in available potassium.

Table 3.2: Initial chemical properties of soil in the experimental field

Soil parameter	Value	Status	Method of estimation
Soil pH (1:2.5 soil : water)	8.0	Alkaline	Glass electrode pH meter method (Jackson, 1973)
EC (dSm^{-1} at 25°C)	0.23	-	Conductivity bridge method (Jackson, 1967)
Organic carbon (%)	0.41	Medium	Walkley and Black’s Wet Oxidation method (Jackson, 1967)
Available N (kg ha^{-1})	133.6	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	24.6	High	Olsen’s method (Olsen *et al*., 1954)
Available K_2O (kg ha^{-1})	276.5	Medium	Flame Photometer method (Richards, 1954)

3.4 Cropping history of the experimental site

Table 3.3: Cropping history of the experimental field

Year	**Rabi**	**Kharif**
2013-14	Wheat	-
2014-15	Wheat	-
2016-17	Wheat	-

3.5 Experimental details

“Effect of fertilizer levels and herbicides on wild oat management in wheat"

Table 3.4: Experimental details for field and screen house

Experimental details	**Field**	**Screen house**
Location	**CCS HAU Agronomy Research Farm**	**CCS HAU Agronomy Screen house**
Design	Split plot	Factorial CRD
Spacing	20 cm x10 cm	10 Plants pot^{-1}
Gross plot size	13.5 m x 2.4 m	10 x 10 inches (diameter x height)
Season/year	*Rabi*- 2015-16 and 2016-17	*Rabi*-2015-16 and 2016-17
Variety	Wheat: WH 1105	Wild oat

3.5.1 Treatment details for field and screen house

A. Main treatments (Fertilizer levels):

F_1: Recommended dose of fertilizer (150 kg N + 60 kg P_2O_5 + 60 kg K_2O + 25 kg $ZnSO_4$ ha^{-1})

F_2: 110 % Recommended dose of fertilizer

F_3: 120 % Recommended dose of fertilizer

B. Sub treatments (Wild oat management practices):

W_1: Clodinafop 60 g ha^{-1}

W_2: Sulfosulfuron 25 g ha^{-1}

W_3: Pinoxaden 50 g ha^{-1}

W_4: Metribuzin 175 g ha^{-1}

W_5: Pendimethalin 1.5 kg ha^{-1}

W_6: Pendimethalin + metribuzin (1.5 kg ha^{-1}, Ready-mix)

W_7: Weed free

W_8: Weedy check

Note: Pendimethalin 1.5 kg ha^{-1} and Pendimethalin + metribuzin (1.5 kg ha^{-1}, Ready-mix) are pre-emergence herbicides and all others are post emergence application. In screen house weed free treatment has been omitted and all other treatments and their combinations remain the same.

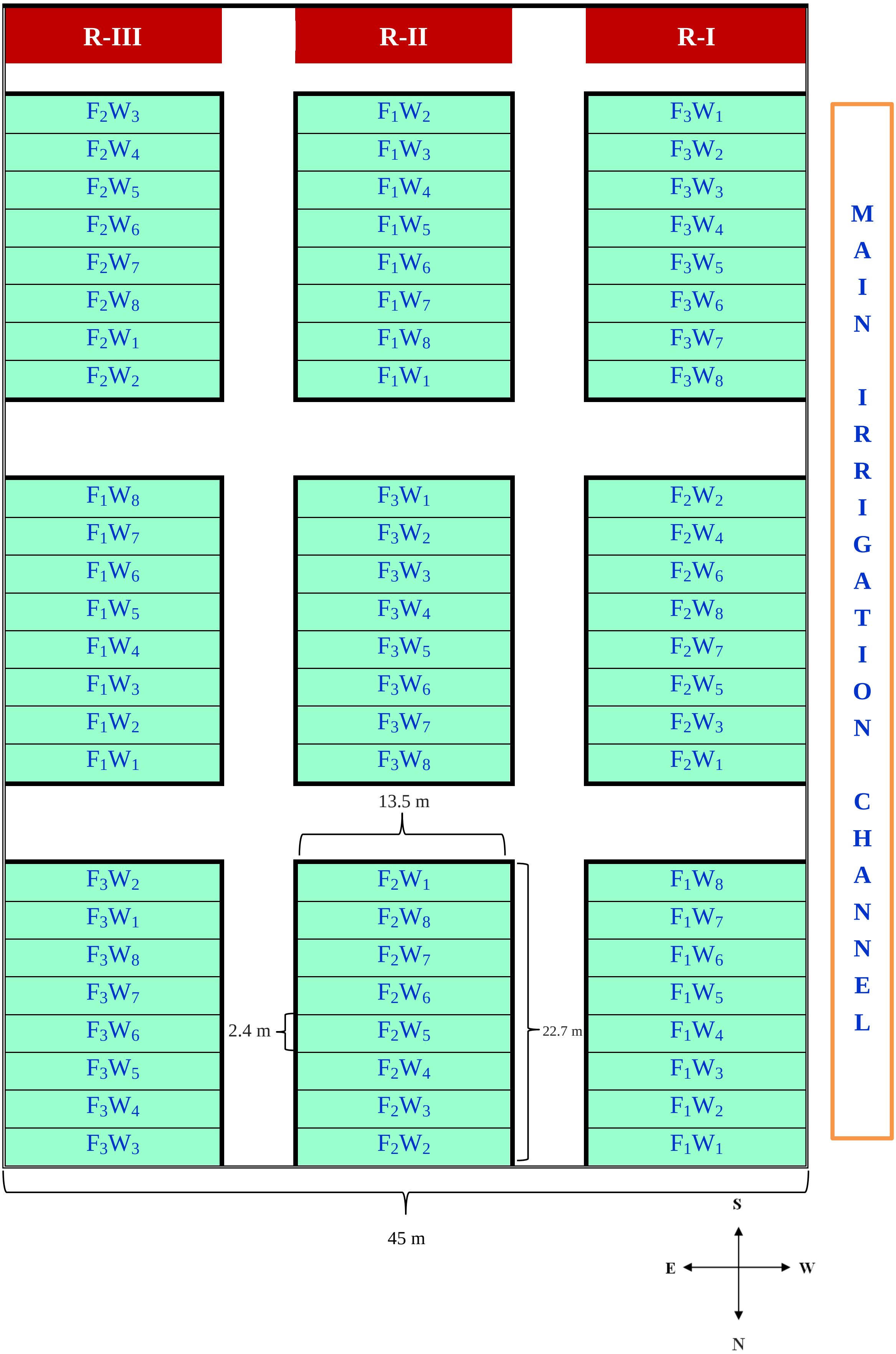


Fig 3.2: Layout of the experiment

3.6. Cultural operations

3.6.1 Tillage details

First, demarcation of blocks according to the main plot treatments (fertilizer levels) was done so as to separate blocks. Two harrowing's + two passes of cultivator followed by planking was done as preparatory tillage, during both the crop seasons. Thereafter layout was done according to prepared plan of layout as depicted in Fig. 3.3.

3.6.2 Fertilizer application

The nitrogen as per the treatment (RDF 100 %, RDF 110 % and RDF 120 % , phosphorus (60 kg P_2O_5 ha^{-1}), potassium (60 kg ha^{-1}) and 25 kg $ZnSO_4$ ha^{-1} were applied to wheat during both the seasons. Complete phosphorus and potassium and half of nitrogen as treatments was applied before sowing and remaining half of nitrogen was top dressed after first irrigation. The sources of nitrogen and phosphorus ware urea and di ammonium phosphate respectively. K_2O in the form of muriate of potash and Zn the form of $ZnSO_4$ was drilled before sowing of the experiment. The other treatments 110 % and 120 % RDF were calculated and applied same as the RDF. In screen house different nutrient levels (RDF, 110 % RDF and 120 % RDF) were used for calculation based on weight of soil in pots. Weight of soil present in pots × nutrient required hectare^{-1} were divided by weight of soil per hectare (2.24×10^6) gives exact amount of nutrients required by the particular pot.

3.6.3 Harvesting and threshing

The wheat crop was harvested manually on 27th March 2016 and on 14th April 2017, and in screen house wild oat was harvested on 23rd March 2016 and on 13th March 2017. Prior to the final harvest of crop, plants from one meter row length in each plot were harvested for recording of yield attributes. Two rows from both sides and half-meter length from each side of the plot across the row were harvested to avoid border effect. The crop in the respective plots was left for sun drying after tagging. Before threshing, the biological yield (straw + grain) of net plot was recorded with spring balance. The crop was threshed plotwise with the help of the mini thresher and grain yield was recorded accordingly. A small sample of grain was drawn from each plot for estimating test weight.

Table 3.5: Schedule of cultural operations carried out in the experimental field

Sr. No.	Operations	Year		Details of operations
		2015-2016	2016-2017	
1.	Pre- sowing irrigation	27.10.2015	17.11.2016	Flood method of irrigation was used
2.	Sowing	09.11.2015	29.11.2016	Crop was sown with the recommended seed rate (100 kg ha^{-1}) and spacing (20 X 10 cm) and fertilizer rate (RDF, 110 % RDF & 120 % RDF ha^{-1}) according to university package of practices using seed-cum- fertilizer drill.
3.	Layout	10.11.2015	30.11.2016	Layout was done by using rope and hand hoe
4.	Application of pre-emergence (PRE) herbicides	10.11.2015	30.11.2016	Using flat fan nozzle mounted on a knapsack sprayer with a spray discharge of 120 l ha^{-1} at 42 p.s.i. pressure
5.	Top dressing	14.12.2015	3.1.2017	The fertilizers were applied according to the university package of practices by broadcasting in field according to the fertilizer levels in the experiment
6.	HW at 30 and 60 DAS (Weed free)	15.12.2015	01.01.2017	By using sickle/ Khurpa/ Kasola, weeds were removed as and when they appeared
7.	Application of post-emergence herbicides	16.12.2015	03.01.2017	Using flat fan nozzle mounted on a backpack sprayer with a spray discharge of 120 l ha^{-1} at 42 p.s.i. pressure
8.	Application of POE herbicides for broad leaves weeds	16.12.2015	15.01.2017	Using flat fan nozzle mounted on a backpack sprayer with a spray discharge of 120 l ha^{-1} at 42 p.s.i. pressure
9.	Harvesting	27.03.2016	14.04.2017	At the ground level by sickle
10.	Threshing	07.04.2016	30.04.2017	By using crop thresher

Table 3.6: Schedule of cultural operations carried out in the screen house

Sr. No.	Operation	Year		Details of operation
		2015-2016	2016-2017	
1.	Pot filling	27.10.2015	17.11.2016	The pots were filled according to the standard proportion of soil and sand. The FYM, sand and inorganic nutrients were added before filling in 3:3:1 respectively.
2.	Sowing	09.11.2015	29.11.2016	Dibbling of wild oat seeds was done manually. Ten seeds were sown in each pot.
3.	(PRE) Application of pre-emergence herbicides	10.11.2015	30.11.2016	Using flat fan nozzle mounted on a backpack sprayer with a spray discharge of 120 l ha^{-1} at 42 p.s.i. pressure
4.	Top dressing	11.12.2015	29.12.2016	Fertilizers were added according to the dosage and calculated according to the formula.
5.	(POE) Application of post-emergence herbicides	16.12.2015	03.01.2017	Using flat fan nozzle mounted on a backpack sprayer with a spray discharge of 120 l ha^{-1} at 42 p.s.i. pressure
6.	Harvesting	23.03.2016	13.04.2017	At the base level by surgical blade

3.7 Characteristics of herbicides used in the pot and field experiments

3.7.1 Clodinafop-propargyl

Common name : Clodinafop-propargyl

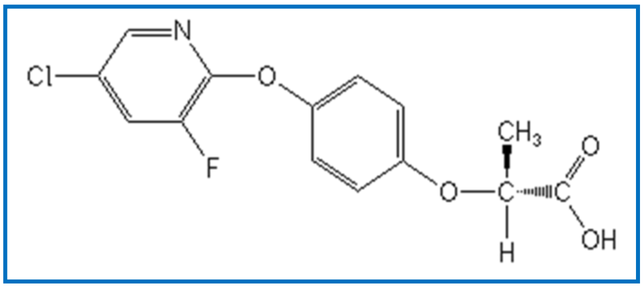
Herbicide group : Aryloxy phenoxy propionate (Fop)

Molecular formula : $C_{17}H_{13}C_lFNO_4$

Trade name : Topik

Formulation : 15 WP

Structural formula:



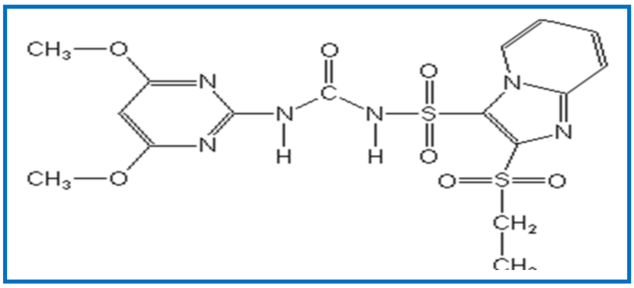
IUPAC name: prop-2-ynyl, (R)-2-[4-(5-chloro-3-fluoro-2yridyloxy) phenoxy] propionate

Mode of action: Post-emergent, systemic grass herbicide inhibits lipid biosynthesis (ACCase) and affects meristematic tissue of weeds.

3.7.2 Sulfosulfuron

Common name	: Sulfosulfuron
Herbicide group	: Sulfonylureas
Molecular formula	: $C_{16}H_{18}N_6O_7S_2$
Trade name	: SF-10
Formulation	: 75 WG

Structural formula:



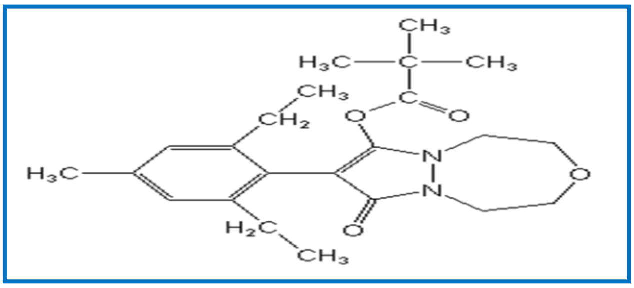
IUPAC name: 1-(4,6-dimethoxypyrimidin-2-yl)-3-(2-ethylsulfonylimidazo[1,2*a*] pyridin-3-ylsulfonyl) urea

Mode of action: Post-emergent, systemic herbicide absorbed by the root system and/or leaf surface and translocated to symplast and apoplast. Inhibits acetolactate synthase ALS (Aceto hydroxyl acid synthase AHAS).

3.7.3 Pinoxaden

Common name	: Pinoxaden
Herbicide group	: Phenyl pyrazoline (DEN)
Molecular formula	: $C_{23}H_{32}N_2O_4$
Trade name	: Axial
Formulation	: 5 EC

Structural formula:



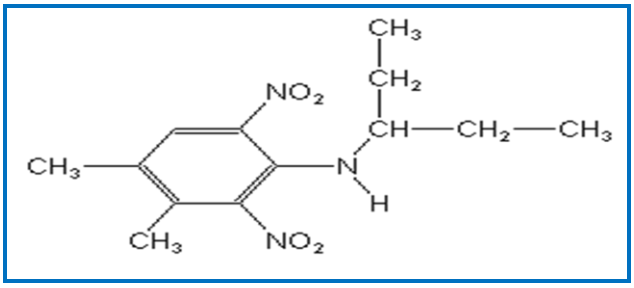
IUPAC name:8-(2,6-diethyl-*p*-tolyl)-1,2,4,5-tetrahydro-7-oxo-7-*H*-pyrazolo[1,2-*d*] [1,4,5]oxadiazepin-9-yl 2,2- dimethyl propionate

Mode of action: Inhibits the enzyme Acetyl-Coenzyme-A-Carboxylase (ACCase) thus inhibiting the production of fatty acids and as a final consequence interrupts the formation of bio membranes.

3.7.4 Pendimethalin

Common name	: Pendimethalin
Herbicide group	: Dinitroaniline
Molecular formula	: $C_{13}H_{19}N_3O_4$
Trade name	: Stomp
Formulation	: 30 EC

Structural formula:



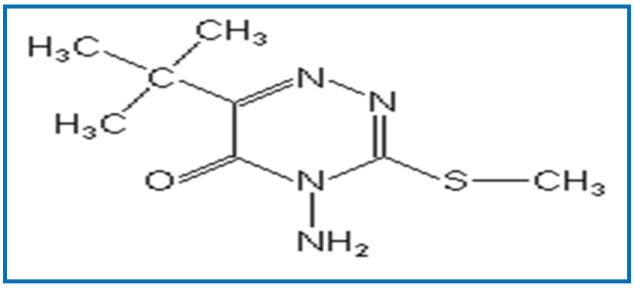
IUPAC name: *N*-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine

Mode of action: Selective, inhibition of mitosis and cell division and micro tubule assembly. Inhibition is the main mechanism and is absorbed by roots and leaves.

3.7.5 Metribuzin

Common name	: Metribuzin
Herbicide group	: Triazinones
Molecular formula	: C8H14N4OS
Trade name	: Sencor
Formulation	: 75 WP

Structural formula:



IUPAC name: 4-amino-6-*tert*-butyl-4, 5-dihydro-3-methylthio-1, 2, 4-triazin-5-one.

Mode of action: Selective herbicide. It acts by inhibiting photosystem II of photosynthesis by disrupting electron transfer. This results in death due to starvation in the target plant.

3.8 Treatment evaluation

3.8.1 Wheat

3.8.1.1 Phenology

Phenological development of the crop observed and recorded in terms of number of days taken when 50 % of the plants reached the particular phenological stage. Anthesis and spike initiation stage was observed visually. Milk stage was determined by pressing the grains between thumb and index finger. Somewhat milky fluid came out of grain as a result of pressing. Physiological maturity was determined by pressing the grain between thumb and index finger. At this stage, the material inside the grain is solid and hard and does not yield to mild pressure.

3.8.1.2 Growth studies

Observations on growth parameters *viz.*, plant height, number of tillers, dry matter production, leaf area, lux meter readings, absolute growth rate and crop growth rate were recorded at 30, 60, 90, 120 days after sowing (DAS) and at harvest from each plot. The methodology for each of them is given below:

3.8.1.2.1 Plant height (cm)

Three plants were tagged at random in each plot for recording plant height at different stages. Plant height (cm) was recorded from the base of the main stem up to the highest growing tip.

3.8.1.2.2 Number of tillers (mrl)

The number of tillers was counted per metre row length from third row on either side in each plot, representing the whole plot, at 60, 90, 120 DAS and at harvest.

3.8.1.2.3 Leaf area

Separated leaves for dry matter were used to measure leaf area with the help of Laser Area Meter (CI-203), CID, Inc. (USA). Leaves per metre row length from randomly selected rows in net plot area were used and calculated by taking length × breadth × number of leaves and multiplied by K factor (0.75) during both the crop seasons.

3.8.1.2.4 Leaf area index (LAI)

The leaf area index is defined as leaf area (assimilatory source) per unit land area. It was calculated at 30, 60, 90 and 120 DAS as per the formula given by Watson (1952).

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Total land area}}$$

3.8.1.2.5 Dry matter production (g)

Plants in 0.25 metre row length from the second row on either side in each plot, representing the whole plot, were cut close to the ground at 30, 60, 90, 120 DAS and at harvest to record dry matter accumulation per metre row length. At the time of selection, it was taken care that area of 0.50 metre near the bunds is excluded for sampling. These samples were first sun dried and then oven dried at 65 ± 2^0 C till a constant weight was obtained at each stage. After drying, the samples were weighted for recording dry weight and computed for per metre row length in grams.

3.8.1.2.6 Absolute growth rate (g day^{-1})

AGR is defined as growth rate of plant at any given time. It was calculated at 0-30, 30-60, 60-90 and 90-120 DAS intervals as per the formula given by Radford (1967).

$$\text{AGR (g day}^{-1}\text{)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2, respectively

3.8.1.2.7 Crop growth rate (g m^{-2} day^{-1})

The dry matter data recorded at 30, 60, 90 DAS and at maturity were used to calculate the crop growth rate (CGR). The CGR was worked out with following formula:

$$\text{CGR} = \frac{W_2 - W_1}{(t_2 - t_1)\, S}$$

Where, W_1 and W_2 are dry weights of plants at time t_1 and t_2 respectively.

$t_2 - t_1$ is the interval of time in days, S is land area (m^{-2}) occupied by plants

3.8.1.3 Yield parameters

3.8.1.3.1 Effective tillers (per metre row length)

Productive tillers were considered those tillers which produced ears completely filled with grains out of total tillers recorded with in a running metre row length. The effective tillers were counted per metre row length from third row on either side in each plot, representing the whole plot at harvest.

3.8.1.3.2 Spike length (cm)

Five representative spikes were harvested from marked rows. The spike length (cm) was measured from the base of the peduncle (lower spikelet) to the tip of the top spikelet.

3.8.1.3.3 Number of spikelets per spike (No.)

From the spikes selected for measuring spike length, the spikelets were separated from spike and the total number of spikelets per spike was counted.

3.8.1.3.4 Number of grains per spike (No.)

From the spikes selected for measuring spike length, the grains were separated from spikelets and the total number of grains per spike was counted and number of grains per spikelet was calculated.

3.8.1.3.5. Test weight (g)

A composite sample of grains was taken from the produce of each net plot and thousand grains were counted manually and the weight of samples was taken in g.

3.8.1.3.6 Biological yield (q ha^{-1})

After harvesting the net plot area, the bundles of wheat crop were sun dried for four days and then weight was recorded and converted into q ha^{-1} for calculating biological yield.

3.8.1.3.7 Grain and straw yields (q ha^{-1})

Grains were separated with the help of mini plot thresher from biological yield obtained from net area of each plot. The grain yield obtained from net plot area was converted into q ha^{-1}. Straw yield was worked out by subtracting the grain yield from total biological yield of net plot area and expressed in q ha^{-1}.

3.8.1.3.8 Harvest index

Harvest index, which is the ratio of economic yield to biological yield expressed in per cent, was worked out by following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.8.2 Wild oat

3.8.2.1 Visual control of weeds

Visual control of *Avena ludoviciana* was recorded at 45 and 120 days after sowing. It was rated on 0-100 per cent scale (0 = no control and 100 = complete control of *Avena ludoviciana*). This data was recorded by comparison of each treatment with unsprayed weedy check in both field and screen house (0 per cent control).

3.8.2.2 Density of wild oat (plants m^{-2})

The density of *Avena ludoviciana* was determined by quadrate method (Mishra and Puri, 1954). The quadrate (0.5 m^{-2}) was thrown randomly at two places in each plot at 30, 60, 90, 120 DAS and at harvest. The weeds inside the quadrate were counted and the average of two quadrates was converted to plants m^{-2}.

3.8.2.3 Dry weight (g m^{-2})

The weeds present within the quadrate from two places selected at random from each plot were taken for dry matter accumulation at 30, 60, 90, 120 DAS and at harvest. These samples were first dried under the sun and then kept in oven at $65\pm5\,^{0}C$ till a constant weight was achieved. The dried samples were weighed and the final dry weight of *Avena ludoviciana* and broad leaf weeds was expressed as g m^{-2}.

3.8.2.4 Weed control efficiency (%)

The weed control efficiency (WCE) was calculated at harvest by the formula:

$$\text{WCE (\%)} = \frac{\text{Dry weight of weeds in weedy plot} - \text{Dry weight of weeds in treatment plot}}{\text{Dry weight of weeds in weedy plot}} \times 100$$

3.8.2.5 Panicle length (cm)

Five randomly selected panicles from five randomly selected plants were taken from each plot and the length of panicle was measured, averaged and expressed in cm.

3.8.2.6 Seeds panicle^{-1}

Five randomly selected panicles from five randomly selected plants were taken from each plot and the number of seeds was counted, averaged and expressed as seeds per panicle^{-1}.

3.8.2.7 Days to 50 % flowering

The plants were counted on daily basis in the net plot rows for flowering (anthesis) and the day on which half of the plants were in flowering is noted down as the days taken to 50 % flowering**.**

3.8.2.8 Days to 50 % spike emergence

The plants from the net plot rows were counted on daily basis till the day when spike was clearly visible in half of the plants and the day is marked as days to 50 % spike emergence.

3.8.2.9 Photosynthetically active radiation interception (%)

Penetration of photosynthetically active radiation (PAR) in the range of 0.40 to 0.70 micron (400-700 µ) was measured between 12:00 to 2:00 P.M. These observations were recorded at 60, 90 and 120 DAS. Readings were recorded with Lux Meter by placing it at the top of the crop canopy and at the soil surface beneath the crop canopy. These data were used for calculating the photosynthetically active radiation interception by crop according to following formula

$$\text{PARI (\%)} = \frac{\text{PAR above crop canopy} - \text{PAR at soil surface}}{\text{PAR above crop canopy}} \times 100$$

3.9 Economic analysis

3.9.1 Cost of cultivation (Rs. ha^{-1})

The cost of various inputs used and the prices of outputs in the prevailing local markets were considered for cost of cultivation the details of which are given in appendix-III.

3.9.2 Gross return (Rs. ha^{-1})

The price of wheat prevailing in the market at the time of harvest was obtained from market and this price was used for the calculation of gross returns.

3.9.3 Net returns (Rs. ha^{-1})

Net returns were worked out by subtracting the total cost of cultivation from total gross income.

3.10 Statistical analysis

The experimental data collected on various growth and yield components of plant were subjected to Fisher's method of "Analysis of variance" (ANOVA) as outlined by Gomez and Gomez (1984). Whenever F-test was significant for comparison amongst the treatments means, an appropriate value of critical differences (CD) was worked out. All the data were analyzed and the results are presented and discussed at a probability level of 5 per cent and correlation study was done as given by Gomez and Gomez (1984).

CHAPTER-IV

RESULTS

The field and pot experiments under the investigation entitled, **“Effect of fertilizer levels and herbicides on wild oat management in wheat”** were carried out during *rabi* seasons of 2015-16 and 2016-17. The results obtained during the course of present investigation are presented and described with the help of suitable tables and figures in this chapter.

4.1.1 Plant height (cm)

Plant height of wheat varied significantly due to fertilizer levels and wild oat management treatments expect at 30 DAS are presented in the Tables 4.1 and 4.2. At 60, 90, 120 DAS and at harvest in pooled data as well as individual years data plants were significantly taller with 120 % recommended dose of fertilizer (RDF) *i.e.,* (39.5, 76.4, 82.8 and 84.4 cm, at 60, 90, 120 DAS and at harvest respectively) as compared to RDF (36.4, 71.9, 78.2 and 79.6 cm, at 60, 90, 120 DAS and at harvest respectively) however 120 % RDF was statistically at par with 110 % RDF.

Among the wild oat management treatments; plant height of wheat at 60, 90, 120 DAS and at harvest varied significantly. Weed free check (48.5, 90.4, 98.1 and 99.8 cm, respectively) and application of pinoxaden @ 50 g ha^{-1} (47.9, 89.9, 97.6 and 99.6 cm, respectively) recorded significantly more pooled mean plant height compared to rest of the treatments, but were statistically at par with each other. Significantly shorter plants were recorded in weedy check (29.4, 59.4, 65.5 and 66.3 cm, respectively) followed by pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1}. Clodinafop @ 60 g ha^{-1} resulted in significantly taller plants (41.3, 80.6, 87.1 and 88.6 cm, respectively) when compared with sulfosulfuron @ 25 g ha^{-1} (38.2, 75.1, 81.2 and 88.9 cm, at 60, 90, 120 DAS and at harvest respectively) but was significantly shorter plants than with pinoxaden @ 50 g ha^{-1} (47.9, 89.9, 97.6 and 99.6 cm, respectively).

The interaction effect of fertilizer levels and wild oat management treatments was non-significant with respect to plant height at 30 DAS. However, at later growth stages of crop *i.e.*, 60, 90, 120 DAS and at harvest, fertilizer levels and wild oat management interaction was significant. Application of 120 % RDF with weed free situation (F_3W_7) resulted in significantly taller plants of wheat (49.7, 92.6, 99.3 and 101.5 cm, respectively) than all other treatment combination except the application of 120 % RDF with pinoxaden @ 50 g ha^{-1} (49.15, 91.8, 98.9 and 100.8 cm, respectively). Treatment combinations *viz.* F_1W_7, F_2W_7, F_1W_3, F_2W_3 and F_3W_3 had significantly taller plants than rest of the treatment combinations but were statistically at par with each other. The treatment combinations resulted in significantly taller plants than RDF in weedy check (26.3, 54.9, 60.8) (Table. 4.1 and 4.2).

Table 4.1: Plant height (cm) of wheat at 30, 60 and 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS				60 DAS												90 DAS											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	21.3	21.4	22.4	**21.7**	36.0	40.0	41.2	39.1	41.1	44.5	45.1	43.6	38.6	42.3	43.2	**41.3**	72.0	78.9	80.4	77.1	80.6	85.7	86.4	84.2	76.3	82.3	83.4	**80.7**
W_2	21.9	22.0	23.0	**22.3**	33.4	37.1	38.1	36.2	37.2	41.6	42.1	40.3	35.3	39.3	40.1	**38.2**	66.3	73.4	75.5	71.7	74.8	79.7	80.7	78.4	70.6	76.6	78.1	**75.1**
W_3	22.5	21.9	23.4	**22.6**	46.2	45.6	44.4	45.4	52.1	49.8	49.7	50.5	47.1	47.7	49.1	**48.0**	89.4	85.5	84.3	86.4	94.1	93.3	92.8	93.4	88.6	89.9	91.8	**89.9**
W_4	22.3	21.6	22.6	**22.1**	27.4	30.4	32.1	30.0	32.2	36.2	37.0	35.1	29.8	33.3	34.6	**32.6**	58.0	63.5	64.8	62.1	65.2	69.5	70.8	68.5	61.6	66.5	67.8	**65.3**
W_5	22.4	22.7	22.8	**22.6**	27.3	30.3	32.4	30.0	32.2	36.2	37.0	35.1	29.7	33.2	34.7	**32.5**	57.4	63.0	64.0	61.5	65.0	69.3	70.5	68.3	61.2	66.2	67.3	**64.9**
W_6	21.5	22.5	22.1	**22.0**	30.3	34.3	35.4	33.3	35.4	38.2	39.8	37.8	32.9	36.2	37.6	**35.6**	62.3	67.7	71.1	67.0	71.0	76.8	76.7	74.8	66.6	72.2	73.9	**70.9**
W_7	22.0	22.0	21.6	**21.9**	47.0	45.9	44.5	45.8	52.3	51.0	50.0	51.1	47.2	48.5	49.7	**48.5**	90.4	85.9	84.8	87.0	94.7	93.6	92.9	93.7	88.9	89.7	92.6	**90.4**
W_8	21.5	21.7	20.4	**21.2**	23.4	27.9	28.1	26.5	29.2	33.2	34.8	32.4	26.3	30.5	31.5	**29.4**	51.2	58.4	60.5	56.7	58.6	62.2	65.5	62.1	54.9	60.3	63.0	**59.4**
Mean	**22.0**	**22.0**	**22.3**	-	33.9	36.4	37.0	-	39.0	41.3	42.0	-	**36.4**	**38.9**	**39.5**	-	68.4	72.0	73.2	-	75.5	78.8	79.5	-	**71.9**	**75.4**	**76.4**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.3		**NS**		0.3		1.2		0.3		1.3		0.3		**1.1**		0.5		2.1		0.3		1.3		0.3		**1.1**	
W	0.5		**NS**		0.6		1.6		0.6		1.8		0.4		**1.2**		0.7		2.0		0.6		1.6		0.5		**1.3**	
W at F	0.9		**NS**		1.0		2.8		1.1		3.2		0.8		**2.2**		1.2		3.4		1.0		2.8		0.8		**2.2**	
F X W	0.9		**NS**		1.0		2.7		1.1		3.1		0.8		**2.2**		1.2		3.5		1.0		2.8		0.8		**2.2**	

Table 4.2: Plant height (cm) of wheat at 120 DAS and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

W M T	120 DAS												At harvest											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	77.3	85.5	86.4	83.1	88.6	91.7	92.8	91.0	83.0	88.6	89.6	**87.1**	79.1	87.3	88.1	84.8	89.8	93.2	94.3	92.4	84.4	90.2	91.2	**88.6**
W_2	71.3	80.4	81.2	77.6	83.2	85.4	86.1	84.9	77.3	82.9	83.6	**81.3**	73.5	81.3	83.0	79.3	84.2	87.5	88.0	86.6	78.8	84.4	85.5	**82.9**
W_3	94.4	92.4	91.8	92.9	103.6	102.1	101.6	96.7	96.7	97.3	99.0	**97.7**	96.5	94.6	93.9	95.0	105.2	104.4	103.5	104.4	98.7	99.5	100.8	**99.7**
W_4	62.3	69.0	70.6	67.3	71.7	75.4	76.8	74.6	67.0	72.2	73.7	**71.0**	64.0	71.7	73.0	69.6	72.1	77.4	78.3	75.9	68.0	74.6	75.7	**72.8**
W_5	62.2	68.9	70.4	67.2	71.1	75.2	76.4	74.2	66.7	72.1	73.4	**70.7**	64.3	71.3	72.6	69.4	72.0	77.3	78.1	75.8	68.1	74.3	75.3	**72.5**
W_6	67.0	74.6	76.4	72.7	78.1	81.7	82.2	80.7	72.5	78.1	79.3	**76.7**	68.1	76.1	78.1	74.1	79.1	81.7	84.0	81.6	73.6	78.9	81.1	**77.9**
W_7	94.5	93.0	91.8	93.1	104.2	102.6	102.2	103.0	97.0	97.8	99.4	**98.0**	97.7	95.0	92.9	95.2	105.3	104.7	103.6	104.5	98.2	99.9	101.5	**99.9**
W_8	57.1	65.5	66.7	63.1	64.5	68.4	70.8	67.9	60.8	66.9	68.8	**65.5**	58.0	66.6	67.5	64.0	65.0	69.3	71.5	68.6	61.5	68.0	69.5	**66.3**
Mean	73.3	78.7	79.4	-	83.1	85.3	86.1	-	**78.2**	**82.0**	**82.8**	-	75.1	80.5	81.2	-	84.1	86.9	87.7	-	**79.6**	**83.7**	**84.4**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.4		1.4		0.3		1.3		0.3		**1.1**		0.3		1.3		0.3		1.3		0.3		**1.3**	
W	0.7		2.1		0.6		1.7		0.5		**1.4**		0.6		1.7		0.5		1.3		0.4		**1.2**	
W at F	1.3		3.7		1.0		3.0		0.9		**2.5**		1.1		3.0		0.8		2.3		0.7		**2.0**	
F X W	1.2		3.6		1.0		2.9		0.9		**2.5**		1.0		3.0		0.8		2.4		0.7		**2.1**	

4.1.2 Leaf area index

Leaf area index of wheat varied significantly due to fertilizer levels and wild oat management treatments at different growth stages except at 30 DAS where non-significant difference was recorded, (Tables 4.3 and 4.4). At, 60, 90 and 120 DAS; pooled data as well as individual year pooled mean, leaf area index with the application of RDF was significantly higher (4.1, 5.93 and 3.57 respectively) when compared with 120 % RDF (3.8, 5.4 and 3.2, respectively), however, RDF was at par with 110 % RDF (4.08, 5.91 and 3.51, respectively). The highest values of leaf area index was recorded at 90 DAS irrespective of fertilizer and weed control treatments.

Weed free check and application of pinoxaden @ 50 g ha^{-1} recorded significantly higher pooled mean leaf area index of the crop at 60, 90 and 120 DAS compared to rest of the treatments, though were statistically at par with each other (Tables 4.3 and 4.4). Significantly lower leaf area index of wheat was recorded in weedy check followed by pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} though pendimethalin and metribuzin were significantly higher than the weedy but statistically similar to each other. Clodinafop @ 60 g ha^{-1} recorded significantly higher leaf area index of the crop when compared with sulfosulfuron @ 25 g ha^{-1} but was significantly lower than pinoxaden @ 50 g ha^{-1}. Application of pendimethalin @ 1.5 kg ha^{-1} + metribuzin @ 175 g ha^{-1} produced significantly higher leaf area index at all growth stages except 30 DAS.

The interaction between fertilizer levels and wild oat management treatments were significant at 60, 90 and 120 DAS except at 30 DAS. Significantly lower leaf area index was recorded with combination of 120 % RDF with weedy check (3.13, 4.1 and 2.6) compared to all other treatments application of 110 % RDF with weedy check (3.4, 4.8 and 2.92, respectively) and weedy check in RDF (3.5, 4.8 and 2.9) resulted in similar but significantly higher leaf area index than 120% RDF with weedy check. Application of 120 % RDF with weed free situation (F_3W_7) resulted in significantly higher leaf area index of wheat compared to all other treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3 with which it was at par at 90 and 120 DAS. At the same fertilizer level *i.e.*, RDF or 110 % RDF or 120 % RDF weed free and pinoxaden @ 50 g ha-1 resulted in significantly higher leaf area index as compared to other wild oat management treatments. All wild oat management treatments resulted in higher leaf area index at lower fertilizer level i.e., RDF as compared to higher levels except in W3 and W7 (Tables 4.3 and 4.4).

Table 4.3: Leaf area index of wheat at 30 and 60 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS												60 DAS											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	0.33	0.33	0.32	0.32	0.42	0.41	0.44	0.42	0.37	0.37	0.38	**0.37**	4.04	3.98	3.25	3.75	4.86	4.83	4.52	4.74	4.45	4.40	3.88	**4.25**
W_2	0.30	0.31	0.28	0.30	0.42	0.44	0.43	0.43	0.36	0.37	0.36	**0.37**	3.80	3.68	3.04	3.51	4.70	4.60	4.28	4.52	4.25	4.14	3.66	**4.02**
W_3	0.32	0.32	0.32	0.32	0.44	0.43	0.42	0.43	0.38	0.38	0.37	**0.38**	4.34	4.37	4.44	4.38	4.95	5.04	5.07	5.02	4.64	4.70	4.76	**4.70**
W_4	0.31	0.31	0.31	0.31	0.41	0.43	0.40	0.41	0.36	0.37	0.36	**0.36**	3.35	3.11	2.56	3.01	4.38	4.33	4.05	4.25	3.86	3.72	3.30	**3.63**
W_5	0.31	0.31	0.32	0.31	0.42	0.44	0.44	0.43	0.36	0.37	0.38	**0.37**	3.33	3.08	2.61	3.01	4.37	4.27	4.00	4.21	3.85	3.67	3.31	**3.69**
W_6	0.28	0.29	0.28	0.28	0.43	0.41	0.42	0.42	0.36	0.35	0.35	**0.35**	3.59	3.21	2.92	3.24	4.52	4.50	4.17	4.40	4.06	3.85	3.54	**3.82**
W_7	0.33	0.33	0.33	0.33	0.44	0.43	0.41	0.43	0.38	0.38	0.37	**0.38**	4.35	4.39	4.83	4.53	4.99	5.06	5.10	5.05	4.67	4.72	4.97	**4.79**
W_8	0.30	0.30	0.33	0.31	0.42	0.41	0.44	0.42	0.36	0.35	0.38	**0.36**	2.95	2.71	2.28	2.64	4.12	4.08	3.98	4.06	3.53	3.39	3.13	**3.35**
Mean	0.31	0.31	0.31	-	0.42	0.42	0.43	-	**0.38**	**0.37**	**0.37**	-	3.72	3.57	3.24	-	4.61	4.59	4.40	-	**4.16**	**4.08**	**3.82**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.01		NS		0.01		NS		0.01		**NS**		0.06		0.22		0.01		0.04		0.03		**0.11**	
W	0.02		NS		0.01		NS		0.01		**NS**		0.06		0.18		0.02		0.05		0.03		**0.09**	
W at F	0.03		NS		0.01		NS		0.02		**NS**		0.11		0.31		0.03		0.08		0.05		**0.15**	
F X W	0.03		NS		0.01		NS		0.02		**NS**		0.12		0.33		0.03		0.08		0.06		**0.16**	

Table 4.4: Leaf area index of wheat at 90 and 120 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	**90 DAS**												**120 DAS**											
	2015-16				**2016-17**				**Pooled**				**2015-16**				**2016-17**				**Pooled**			
	Fertilizer levels (F)				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	5.88	5.81	5.13	5.61	6.81	6.75	6.33	6.63	6.35	6.28	5.73	**6.12**	3.53	3.51	3.01	3.35	3.97	3.90	3.66	3.84	3.75	3.70	3.34	**3.60**
W_2	5.62	5.56	4.72	5.30	6.45	6.41	5.99	6.28	6.04	5.99	5.36	**5.79**	3.30	3.25	2.77	3.11	3.81	3.84	3.55	3.73	3.55	3.54	3.16	**3.42**
W_3	6.19	6.23	6.22	6.21	7.14	7.25	7.26	7.22	6.66	6.74	6.74	**6.71**	3.73	3.75	3.75	3.74	4.28	4.34	4.27	4.30	4.01	4.04	4.01	**4.02**
W_4	5.05	5.02	4.04	4.70	5.89	5.87	5.41	5.72	5.47	5.45	4.72	**5.21**	2.81	2.79	2.37	2.66	3.54	3.52	3.30	3.46	3.17	3.16	2.84	**3.06**
W_5	5.04	5.01	4.02	4.69	5.88	5.83	5.35	5.69	5.46	5.42	4.69	**5.19**	2.81	2.78	2.36	2.65	3.51	3.49	3.26	3.42	3.16	3.14	2.81	**3.04**
W_6	5.34	5.28	4.51	5.04	6.19	6.06	5.84	6.03	5.77	5.67	5.17	**5.54**	3.07	3.04	2.64	2.92	3.65	3.69	3.44	3.60	3.36	3.37	3.04	**3.26**
W_7	6.19	6.25	6.25	6.23	7.18	7.35	7.33	7.29	6.69	6.80	6.79	**6.76**	3.75	3.75	3.76	3.75	4.29	4.36	4.25	4.30	4.02	4.06	4.01	**4.03**
W_8	4.20	4.17	3.52	3.96	5.52	5.49	4.80	5.27	4.86	4.83	4.16	**4.62**	2.59	2.55	2.06	2.40	3.31	3.29	3.13	3.24	2.95	2.92	2.60	**2.82**
Mean	5.44	5.42	4.80	-	6.38	6.38	6.04	-	**5.91**	**5.90**	**5.42**	-	3.20	3.18	2.84	-	3.80	3.80	3.61	-	**3.50**	**3.49**	**3.23**	-
	SEm±		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**	
F	0.04		0.17		0.02		0.07		0.02		**0.08**		0.03		0.13		0.02		0.09		0.02		**0.07**	
W	0.06		0.17		0.05		0.15		0.04		**0.11**		0.04		0.10		0.04		0.10		0.03		**0.07**	
W at F	0.10		0.30		0.09		0.27		0.07		**0.19**		0.06		0.18		0.06		NS		0.05		**0.13**	
F X W	0.11		0.30		0.09		0.25		0.07		**0.19**		0.07		0.19		0.06		NS		0.05		**0.13**	

4.1.3 Number of tillers per metre row length

The number of tillers of wheat varied significantly due to fertilizer levels and wild oat management treatments except at 30 DAS (Tables 4.5 and 4.6). At, 60, 90, 120 DAS and at harvest; The number of tillers per metre row length was significantly higher with the application of RDF as compared with 120 % RDF however RDF was at par with 110 % RDF. The reduction in tiller number with the application of higher dose of fertilizer *i.e.* 120 % RDF over RDF was to the tune of 8.3, 8.9, 6.9 and 7.2 percent at 60, 90,120 DAS and at maturity, respectively.

Among the wild oat management treatments, weed free and pinoxaden @ 50 g ha^{-1} being at par with each other resulted in significantly higher number of tillers as compared to rest of the wild oat management treatments during both the years as well as in pooled data at all the growth stages of the crop except at 30 DAS. Clodinafop @ 60 g ha^{-1} recorded significantly higher number of tillers when compared with sulfosulfuron @ 25 g ha^{-1} but was significantly lower than the pinoxaden @ 50 g ha^{-1} at 60, 90, 120 DAS and at harvest. Significantly lower number of tillers was recorded in weedy check among all wild oat management treatments followed by pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} at all growth stages of crop. Metribuzin and pendimethalin were at par with each other though both these treatments resulted in significantly lower number of tillers than the pendimethalin + metribuzin 1.5 kg ha^{-1}.

The interaction effect of fertilizer levels and wild oat management treatments on number of tillers per metre row length varied significantly at 60, 90, 120 DAS (Tables 4.5 and 4.6). Application of 120 % RDF with weed free situation (F_3W_7) resulted in significantly higher pooled mean number of tillers per meter row length (92.1 92.7, 93.1 and 86.1) compared to all other treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3 with which it was at par. Significantly lower number of tillers per meter row length was recorded with the combination of 120 % RDF with weedy check (53.8, 57.8, 58.1 and 51.9) compared to all other treatments followed by 110 % RDF with weedy check (61.3, 64.2, 65.5 and 59.1) and weedy check in RDF (63.8, 68.1, 65.8 and 60.4), RDF and 110 % RDF with weedy check were at par relation with each other but resulted in significantly higher number of tillers than the 120 % RDF with weedy check.

Table 4.5: Total number of tillers per m.r.l of wheat at 30, 60 and 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS (m.r.l)				60 DAS (mrl)												90 DAS (mrl)											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	M_2	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	11.9	12.0	13.2	**12.4**	80.7	79.9	72.8	77.8	88.0	86.6	79.6	84.7	84.4	83.3	76.2	**80.7**	82.0	81.3	76.5	79.9	87.0	85.0	80.0	84.0	84.5	83.1	78.3	**81.3**
W_2	12.1	12.2	13.3	**12.5**	74.4	72.8	66.6	71.3	83.7	81.6	75.1	80.1	79.1	77.2	70.8	**75.7**	78.1	77.2	71.7	75.6	84.0	82.0	76.3	80.8	81.0	79.6	74.0	**76.0**
W_3	12.2	12.4	11.7	**12.1**	86.9	89.3	90.1	88.8	91.2	91.2	93.3	91.9	89.1	90.3	91.7	**90.3**	88.2	89.0	90.7	89.3	92.0	93.0	94.0	93.0	90.1	91.0	91.3	**91.1**
W_4	11.7	12.2	11.5	**11.8**	63.4	59.6	51.0	58.0	75.7	72.7	66.2	71.5	69.6	66.1	58.6	**64.8**	68.9	68.0	63.3	66.8	75.0	73.0	66.0	71.3	72.0	70.5	64.7	**69.0**
W_5	12.0	12.5	12.3	**12.3**	63.5	58.7	49.7	57.3	74.2	71.2	65.8	70.4	68.8	64.9	57.8	**63.9**	68.2	67.2	62.2	65.8	74.0	72.0	65.0	70.3	71.1	69.6	63.6	**68.1**
W_6	12.6	12.6	11.8	**12.3**	68.2	65.8	60.0	64.6	79.6	76.3	70.3	75.4	73.9	71.0	65.2	**70.0**	74.0	73.3	67.0	71.4	82.0	78.0	71.3	77.1	78.0	75.7	69.2	**74.3**
W_7	12.2	12.3	12.1	**12.2**	89.3	90.3	92.0	90.5	91.4	92.4	93.5	92.4	90.3	91.4	92.1	**91.5**	88.3	90.0	91.3	89.9	93.4	94.0	95.0	94.1	90.9	92.0	92.7	**92.0**
W_8	12.0	12.0	12.7	**12.2**	56.4	55.6	48.3	53.5	69.9	67.0	59.3	65.4	63.2	61.3	53.8	**59.4**	61.7	60.5	54.3	58.8	70.0	68.0	61.7	66.6	65.9	64.3	58.0	**62.7**
Mean	**12.1**	**12.3**	**12.3**	-	72.8	71.5	66.3	-	81.7	79.9	75.4	-	**77.3**	**75.7**	**70.9**	-	76.2	75.8	72.1	-	82.2	80.6	76.2	-	**79.5**	**77.9**	**72.4**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.2		NS		0.4		1.7		0.7		2.9		0.5		**2.1**		0.1		0.3		0.6		2.4		0.3		**1.3**	
W	0.2		NS		1.1		3.1		0.8		2.4		0.8		**2.2**		0.6		1.6		0.9		2.7		0.5		**1.5**	
W at F	0.4		NS		1.9		5.4		1.4		4.1		1.3		**3.8**		1.0		2.8		1.6		4.6		0.9		**2.7**	
F X W	0.4		NS		1.8		5.2		1.5		4.4		1.3		**3.8**		0.9		2.6		1.6		4.6		0.9		**2.7**	

Table 4.6: Total number of tillers per m.r.l of wheat at 120 DAS and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	120 DAS (mrl)												At harvest (mrl)											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	82.0	80.0	72.6	78.2	87.2	84.0	78.4	83.2	84.6	82.0	75.5	**82.0**	76.6	75.5	70.3	74.1	82.3	81.0	75.2	79.5	79.4	78.3	72.8	**76.8**
W_2	78.0	75.3	66.2	73.2	82.0	80.4	74.0	78.8	80.0	77.9	70.1	**78.2**	71.9	70.5	65.0	69.1	79.0	78.2	71.8	76.3	75.5	74.3	68.4	**72.7**
W_3	87.0	87.7	88.0	87.6	93.0	94.0	94.7	93.9	90.0	90.8	92.3	**91.7**	82.8	82.3	83.5	82.9	86.0	87.0	88.4	87.1	84.4	84.7	85.9	**85.0**
W_4	71.0	69.7	61.0	67.2	76.0	73.0	65.0	71.3	73.5	71.3	63.0	**69.0**	62.8	62.5	55.8	60.4	70.2	69.0	62.1	67.1	66.5	65.7	59.0	**63.7**
W_5	69.0	67.3	59.3	65.2	75.3	72.3	64.0	70.6	72.2	69.8	61.7	**68.8**	62.5	62.3	55.0	59.9	69.7	68.0	61.1	66.2	66.1	65.2	58.0	**63.1**
W_6	74.0	72.0	64.0	70.0	80.3	77.0	69.3	75.6	77.2	74.5	66.7	**74.5**	68.3	65.0	60.0	64.4	77.1	78.0	70.0	75.0	72.7	71.5	65.0	**69.7**
W_7	88.0	88.7	89.0	88.6	94.0	94.7	95.0	94.6	91.0	91.7	93.1	**92.6**	82.9	82.8	83.0	82.9	86.2	86.3	89.3	87.3	84.5	84.6	86.2	**85.1**
W_8	65.0	62.0	56.0	61.0	71.3	69.0	62.0	67.4	68.2	65.5	59.0	**64.2**	55.2	53.7	49.5	52.8	65.7	64.7	54.4	61.6	60.4	59.2	51.9	**57.2**
Mean	76.8	75.3	69.5	-	82.4	80.5	75.3	-	**79.6**	**78.9**	**74.1**	-	70.4	69.3	65.3	-	77.0	76.5	71.5	-	**73.7**	**72.9**	**68.4**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.6		2.3		0.5		2.2		0.5		**2.1**		0.5		2.0		0.4		1.6		0.3		**1.2**	
W	1.7		4.8		1.5		4.2		0.9		**2.5**		0.7		2.1		0.7		1.9		0.5		**1.3**	
W at F	2.9		NS		2.5		NS		1.5		**4.4**		1.3		3.6		1.2		3.3		0.8		**2.3**	
F X W	2.8		NS		2.4		NS		1.5		**4.4**		1.3		3.7		1.2		3.3		0.8		**2.3**	

4.1.4 Dry matter production (g, m.r.l)

Dry matter production of wheat varied significantly due to fertilizer levels and wild oat management treatments except at 30 DAS (Tables 4.7, 4.8 and Fig. 3, 4). At, 60, 90, 120 DAS and at harvest; pooled data as well as individual year data, shows significantly higher dry matter production of the wheat with RDF (52.4, 148.3, 199.7 and 227.4 g, respectively) which was similar to the application of 110 % RDF (51.7, 147.2, 198.9 and 226.5 g, respectively) whereas, significantly lower dry matter production was observed with the application of 120 % RDF (48.4, 141.2, 191.5 and 220.9 g at 60, 90 120 DAS and at harvest, respectively). Thus RDF resulted in 7.6, 4.8, 4.1 and 2.8 % higher dry matter accumulation as compared to 120 % RDF at 60, 90, 120 DAS and at maturity, respectively.

Clodinafop @ 60 g ha^{-1} recorded significantly higher dry matter production of the wheat (566.5, 156.4, 206.1 and 232.9 g) when compared with sulfosulfuron @ 25 g ha^{-1} (50.7, 148.3, 197.8 and 247.4 g at 60, 90,120 DAS and at maturity, respectively) though significantly lower dry matter than pinoxaden. Weed free check and pinoxaden @ 50 g ha^{-1} produced significantly higher dry matter production of wheat compared to rest of the treatments, though these were statistically at par with each other at 60, 90, 120 DAS and at harvest (Fig. 1 and 2). Significantly lower dry matter production of the wheat was recorded in weedy check (38.4, 114.8, 178.8 and 202.7 g 60, 90,120 DAS and at maturity, respectively) followed by pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1}. Pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} being at par with each other produced significantly lower wheat dry matter than the pendimethalin + metribuzin @ 1.5 kg ha^{-1}, at all growth stages up to maturity except at 30 DAS.

The interaction between fertilizer levels and wild oat management treatments was significant with respect to dry matter production of the crop at 60, 90, 120 DAS and at harvest (Tables 4.7 and 4.8). Significantly lower dry matter production was recorded with the combination of 120 % RDF with weedy check (35.7, 100.2, 166.7 and 195.7 g at 60, 90,120 and at maturity, respectively) compared to all other treatments followed by 110 % RDF with weedy check (39.2, 112.7, 176.7 and 205.3 g). Weedy check in RDF (40.2, 119.1, 178.1 and 207.2 g) produced wheat dry matter as compared to significantly higher than the 120 % RDF with weedy check at all stages except 30 DAS and also over 110 % RDF with weedy check at 90 DAS. Significantly higher dry matter production was recorded with F_3W_7 *i.e.*, application of 120 % RDF with weed free situation (65.1, 170.3, 222.8 and 249.6 g) compared rest of the treatment combinations except F_1W_3, F_2W_3, F_3W_3, F_1W_7 and F_2W_7 (Fig. 3, 4).

Table 4.7: Dry matter (g) of wheat at 30, 60 and 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS (mrl)				60 DAS (mrl)												90 DAS (mrl)											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	M_2	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	6.4	6.6	6.9	**6.6**	51.2	50.6	46.2	49.3	65.7	64.6	58.1	62.8	58.4	57.6	52.2	**56.1**	144.9	143.4	133.7	140.7	176.5	175.3	164.9	172.2	160.7	159.3	149.3	**156.5**
W_2	6.6	6.0	6.3	**6.3**	47.1	46.6	42.0	45.2	59.8	57.2	51.7	56.2	53.5	51.9	46.9	**50.7**	137.4	136.7	125.8	133.3	167.4	165.0	157.6	163.3	152.4	150.8	141.7	**148.3**
W_3	6.0	6.6	6.4	**6.3**	54.2	55.3	56.2	55.2	71.4	72.2	72.8	72.1	62.8	63.8	64.5	**63.7**	152.7	153.4	154.4	153.5	182.6	183.0	184.4	183.3	167.6	168.2	169.4	**168.4**
W_4	6.5	6.7	6.6	**6.6**	41.0	40.6	36.0	39.2	50.6	48.2	44.4	47.7	45.8	44.4	40.2	**43.5**	121.9	120.3	132.0	124.7	146.4	143.5	134.7	141.5	134.1	131.9	133.4	**133.1**
W_5	6.6	6.2	6.2	**6.3**	40.3	40.0	36.1	38.8	49.3	47.4	43.7	46.8	44.8	43.7	39.9	**42.8**	120.5	119.9	100.7	113.7	145.4	143.3	133.8	140.8	132.9	131.6	117.2	**128.3**
W_6	7.1	6.7	6.4	**6.7**	43.6	43.0	39.3	42.0	57.0	55.5	47.0	53.1	50.3	49.2	43.1	**47.5**	127.5	158.0	144.0	143.2	159.5	157.2	153.4	156.7	143.5	157.6	148.7	**149.9**
W_7	6.9	6.7	6.5	**6.7**	55.0	56.0	57.0	56.0	72.0	72.9	73.0	72.6	63.5	64.5	65.0	**64.3**	153.3	154.2	155.3	154.2	183.7	184.2	185.5	184.5	168.5	169.2	170.4	**169.4**
W_8	6.3	5.9	6.5	**6.3**	37.1	36.4	33.3	35.6	43.4	42.0	38.2	41.2	40.3	39.2	35.8	**38.4**	136.1	87.8	79.1	101.0	133.9	130.7	121.3	128.6	135.0	109.2	100.2	**114.8**
Mean	**6.6**	**6.4**	**6.5**	-	46.2	46.1	43.3	-	58.7	57.5	53.6	-	**52.4**	**51.8**	**48.4**	-	136.8	134.2	128.1	-	161.9	160.3	154.4	-	**149.3**	**147.2**	**141.3**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.1		**NS**		0.1		0.5		0.3		1.2		0.2		**0.7**		1.4		5.4		0.8		3.1		0.3		**1.2**	
W	0.2		**NS**		0.4		1.1		0.5		1.5		0.3		**0.9**		2.6		7.4		1.0		2.7		1.5		**4.2**	
W at F	0.3		**NS**		0.7		1.9		0.9		2.6		0.6		**2.6**		4.5		12.8		1.7		4.7		2.6		**7.3**	
F X W	0.3		**NS**		0.6		1.8		0.9		2.5		0.6		**2.5**		4.4		12.6		1.7		5.0		2.4		**6.9**	

Table 4.8: Dry matter (g) of wheat at 120 DAS and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	120 DAS (mrl)												At harvest (mrl)											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	204.5	203.2	188.6	198.8	217.1	215.6	207.9	213.5	210.8	209.4	198.2	**206.1**	228.7	227.4	220.3	225.5	244.3	242.2	233.5	240.0	236.5	234.8	226.9	**232.7**
W_2	192.4	191.9	180.4	188.2	209.5	208.6	199.7	205.9	200.9	200.3	190.0	**197.1**	222.8	220.8	213.3	219.0	235.9	234.5	227.2	232.5	229.3	227.6	220.3	**225.8**
W_3	213.5	213.4	213.9	213.6	227.8	228.0	229.9	228.6	220.7	220.7	221.9	**221.1**	237.7	239.3	242.0	239.7	253.6	254.7	256.1	254.8	245.6	247.0	249.1	**247.2**
W_4	179.1	178.0	168.4	175.2	194.8	193.2	183.4	190.5	186.9	185.6	175.9	**182.8**	208.0	206.1	198.0	204.0	223.6	222.1	211.9	219.2	215.8	214.1	204.9	**211.6**
W_5	178.6	177.7	167.0	174.4	193.6	191.6	182.9	189.4	186.1	184.6	174.9	**181.9**	207.5	205.6	197.0	203.4	222.5	221.0	210.8	218.1	215.0	213.3	203.9	**210.9**
W_6	185.7	184.0	172.6	180.8	202.4	201.8	191.1	198.5	194.1	192.9	181.8	**189.6**	218.3	216.3	206.0	213.6	229.2	227.8	220.7	225.9	223.8	222.1	213.3	**219.7**
W_7	212.5	213.6	215.0	213.7	227.8	229.2	230.6	229.2	220.1	221.4	222.8	**221.4**	238.7	240.3	243.3	240.8	253.6	255.3	256.3	255.1	246.2	247.8	249.8	**247.9**
W_8	168.3	167.2	156.7	164.1	187.7	186.3	176.8	183.6	178.0	176.7	166.8	**173.8**	198.5	197.2	184.7	193.4	215.9	213.6	205.7	211.7	207.2	205.4	195.2	**202.6**
Mean	191.8	191.1	182.8	-	207.6	206.8	200.3	-	**199.7**	**199.0**	**191.6**	-	220.0	219.1	213.1	-	234.8	233.9	227.8	-	**227.4**	**226.5**	**220.4**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.9		3.7		0.8		3.1		0.5		**1.8**		0.3		1.2		0.6		2.3		0.3		**1.1**	
W	1.2		3.3		0.8		2.3		0.7		**1.9**		0.7		1.9		0.9		2.5		0.6		**1.6**	
W at F	2.0		5.8		1.4		4.1		1.2		**3.4**		1.1		3.3		1.5		4.3		1.0		**4.9**	
F X W	2.1		6.0		1.5		4.4		1.2		**3.4**		1.1		3.2		1.5		4.4		1.0		**4.7**	

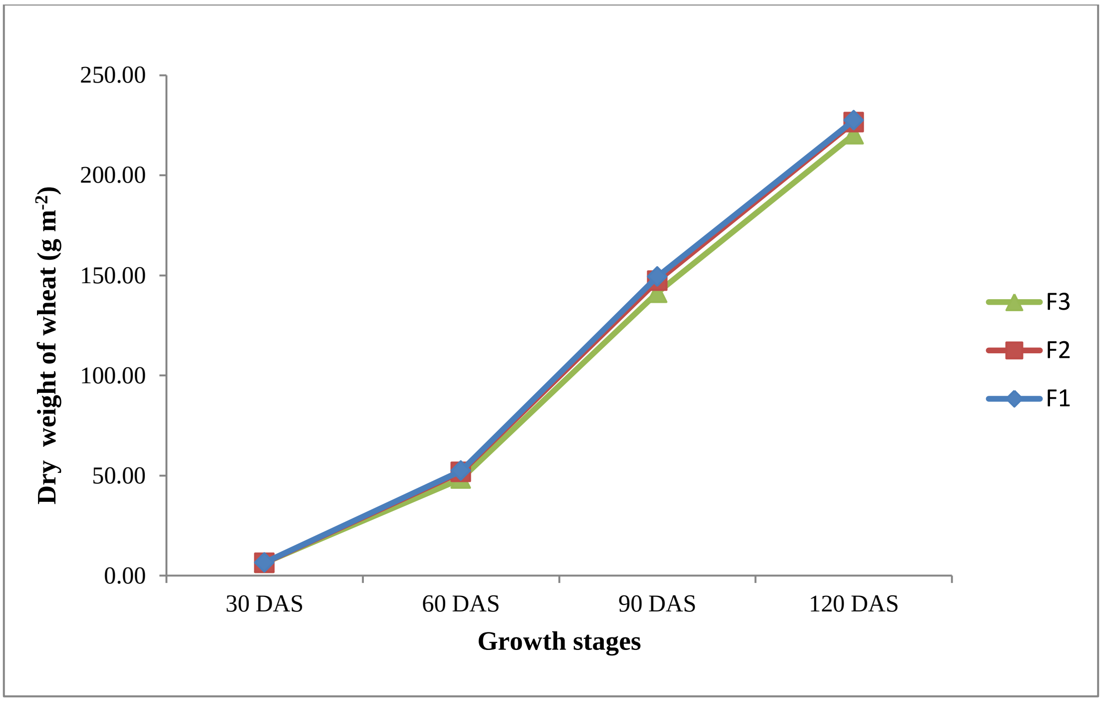


Fig. 3: Dry matter (g m^{-2}) of wheat at 30, 60, 90 and 120 DAS as influenced by fertilizer levels in wheat

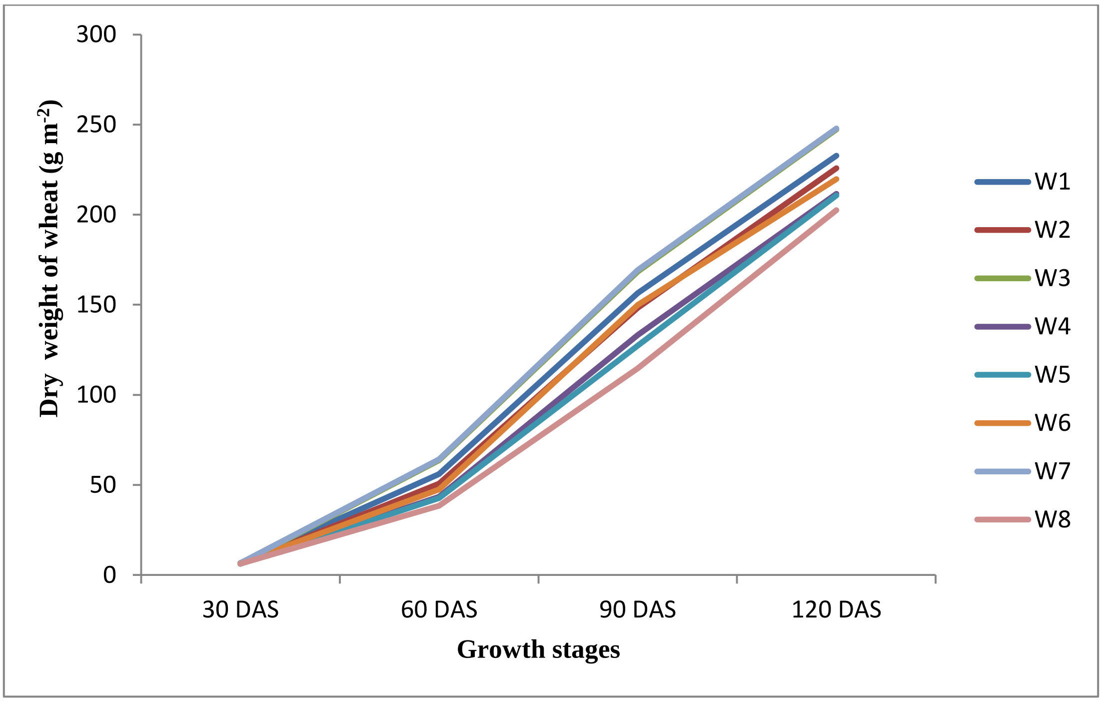


Fig. 4: Dry matter (g m^{-2}) of wheat at 30, 60, 90 and 120 DAS as influenced by wild oat management treatments in wheat

4.1.5 Photosynthetically active radiation interception (PARI)

The data on PARI as influenced by fertilizer levels and wild oat management treatments in wheat was recorded at 60, 90 and 120 DAS are presented in Table 4.9. The PARI increased from 60 DAS to 90 DAS and then declined at maturity. PARI completely depends upon the leaf area index and the bright sunny day.

At 60, 90 and 120 DAS the pooled data as well as individual years PARI with the application of RDF was significantly higher (69.1, 82.3 and 77.9) when compared with 120 % RDF (65.1, 77.1 and 71.8). However, PARI values with were at par with 110 % RDF (68.4, 81.4 and 76. 1).

Pendimethalin @ 1.5 kg ha^{-1} (61.2, 66.9 and 68.73) recorded significantly less PARI followed by and metribuzin @ 175 g ha^{-1} (62.9, 75.9 and 70.83) and weedy check (63.4, 75.9 and 70.8), though metribuzin @ 175 g ha^{-1} and pendimethalin @ 1.5 kg ha^{-1} was at par with each other, but significantly less than the pendimethalin @ 1.5 kg ha^{-1} + metribuzin @ 175 g ha^{-1}, among the wild oat management treatments. Weed free (79.2, 91.8 and 86.7) and pinoxaden @ 50 g ha^{-1} (77.7, 90.2 and 85.2 at 60, 90, 120 DAS and at maturity, respectively) being at par with each other produced significantly more PARI as compared to rest of the wild oat management treatments during both the years as well as in pooled data at all the growth stages of the crop (Table 4.9). Clodinafop @ 60 g ha^{-1} recorded significantly higher PARI (66.7, 79.7 and 74.87) when compared with sulfosulfuron @ 25 g ha^{-1} (64.7, 77.5 and 72.79) though it was significantly less than pinoxaden @ 50 g ha^{-1}. Interaction between Fertilizer levels and wild oat management treatments was non-significant at different growth stages of wheat.

4.1.6 Crop growth rate (g m^{-2} day^{-1})

The data on crop growth rate (g m^{-2} day^{-1}) as influenced by fertilizer levels and wild oat management treatments in wheat and recorded at 30, 60, 90, 120 DAS and at harvest are presented in Table (4.10 and 4.11). Fertilizer levels and wild oat management treatments failed to produce significant variation on CGR of wheat at 30 DAS, however, at two growth stages *i.e.*, 60, 90, DAS; pooled data as well as individual year data indicate significantly higher CGR with the application of RDF (305 and 646 g m^{-2} day^{-1}, respectively) when compared with 120 % RDF (279 and 618 g m^{-2} day^{-1}, respectively) whereas, RDF was at par with 110 % RDF (302 and 636 g m^{-2} day^{-1}, respectively). Fertilizer levels at 120 DAS and at harvest did not show any significant difference with respect to the CGR. RDF resulted 9.29 and 4.49 per cent higher CGR as compared to 120 % RDF at 60 and 90 DAS, respectively.

Table 4.9: Photosynthetically active radiation interception (Lux meter) in wheat at different growth stages as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	60 DAS				90 DAS												120 DAS											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	M_2	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	70.1	67.6	62.5	**66.8**	80.1	77.3	72.1	76.5	85.3	85.1	78.8	83.0	82.7	81.2	75.5	**79.8**	76.1	74.7	68.8	73.2	81.1	77.0	71.5	76.5	78.6	75.9	70.1	**74.9**
W_2	68.1	66.2	60.0	**64.8**	78.2	75.9	69.6	74.6	83.3	82.9	75.2	80.5	80.8	79.4	72.4	**77.5**	74.2	72.6	66.2	71.0	79.2	75.6	68.9	74.6	76.7	74.1	67.6	**72.8**
W_3	76.6	77.6	78.9	**77.7**	86.9	87.3	86.9	87.0	92.3	94.3	93.6	93.4	89.6	90.8	90.2	**90.2**	82.9	83.9	83.6	83.5	87.9	86.9	86.2	87.0	85.4	85.4	84.9	**85.3**
W_4	65.3	64.5	59.1	**63.0**	75.6	74.2	68.5	72.8	81.9	80.2	75.2	79.1	78.8	77.2	71.9	**75.9**	71.6	69.9	65.2	68.9	76.6	73.9	67.9	72.8	74.1	71.9	66.5	**70.8**
W_5	63.7	62.5	57.4	**61.2**	73.9	72.1	65.5	70.5	80.2	79.1	72.1	77.2	77.1	75.6	68.8	**67.1**	69.9	68.8	62.1	67.0	74.9	71.8	64.8	70.5	72.4	70.3	63.5	**68.7**
W_6	66.3	65.4	61.7	**64.5**	76.7	75.1	70.1	74.0	83.0	81.1	76.8	80.3	79.8	78.1	73.5	**77.1**	72.7	70.7	66.8	70.1	77.7	74.7	69.5	74.0	75.2	72.7	68.1	**72.0**
W_7	78.0	79.2	80.6	**79.3**	88.4	88.8	88.7	88.7	94.7	94.8	95.4	95.0	91.6	91.8	92.1	**91.8**	84.4	84.5	85.4	84.8	89.4	88.5	88.1	88.7	86.9	86.5	86.7	**86.7**
W_8	65.2	64.0	61.0	**63.4**	75.6	73.7	69.0	72.8	81.9	79.7	75.7	79.1	78.8	76.7	72.3	**75.9**	71.6	69.3	65.7	68.9	76.6	73.3	68.3	72.8	74.1	71.3	67.0	**70.8**
Mean	**69.2**	**68.4**	**65.1**	-	79.4	78.0	73.8	-	85.3	84.6	80.4	-	**82.4**	**81.3**	**77.1**	-	75.4	74.3	70.5	-	80.4	77.7	73.1	-	**77.9**	**76.0**	**71.8**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.2		**0.8**		0.9		3.4		0.8		3.2		0.5		**1.9**		0.9		3.5		0.9		3.6		0.7		**2.8**	
W	1.0		**1.8**		1.0		3.0		1.1		3.0		1.0		**2.9**		1.1		3.0		1.0		3.0		1.0		**3.0**	
W at F	1.7		**NS**		1.8		NS		1.8		NS		1.8		**NS**		1.8		NS		1.8		NS		1.8		**NS**	
F X W	1.6		**NS**		1.9		NS		1.9		NS		1.7		**NS**		1.9		NS		1.9		NS		1.8		**NS**	

Among the wild oat management treatments, weed free (384, 700 and 347 g m^{-2} day^{-1}, at 60, 90 and 120 DAS, respectively) and pinoxaden @ 50 g ha^{-1} (382, 698 and 351 g m^{-2} day^{-1}) being at par with each other resulted significantly more CGR as compared to rest of the wild oat management treatments during both the years as well as in pooled data at all the growth stages of the crop except 30 ADS and at maturity. Significantly lower CGR was observed in weedy check followed by pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1}. Clodinafop @ 60 g ha^{-1} recorded significantly higher CGR (329, 669 and 331 g m^{-2} day^{-1}, 60, 90 and 120 DAS, respectively) when compared with sulfosulfuron @ 25 g ha^{-1} (296, 650 and 325 g m^{-2} day^{-1}) though it was significantly lower than the pinoxaden @ 50 g ha^{-1} at 60 and 90 DAS respectively. At harvest, the crop growth rate was found to be non-significant with fertilizer levels as well as different wild oat management treatments and their interactions.

The interaction between fertilizer levels and weed management treatments was significant with respect to crop growth rate only at 60 and 90 DAS (Tables 4.10 and 4.11). Significantly lower crop growth rate was recorded with the combination of 120 % RDF with weedy check (194 and 429 g m^{-2} day^{-1}) compared rest of the other treatments followed by 110 % RDF with weedy check (222 and 466 g m^{-2} day^{-1}) and weedy check in RDF (226 and 631 g m^{-2} day^{-1}), RDF and 110 % RDF show at par relation with each other though significantly higher than the 120 % RDF with weedy check at both these stages. Application of 120 % RDF with weed free situation (F_3W_7) resulted in significantly higher CGR (390 and 702 g m^{-2} day^{-1}) as compared to all other treatment combinations at both stages.

4.2 Yield attributes and yield of wheat

The data on yield components *viz.,* number of productive tillers (m.r.l), spike length (cm), grains $spike^{-1}$ (No.), spikelets $spike^{-1}$ (No.), 1000 grain weight (g), as well as biological yield (q ha^{-1}), straw yield (q ha^{-1}) and grain yield (q ha^{-1}) as influenced by fertilizer levels and herbicides on wild oat management in wheat are presented in Tables 4.12 to 4.15.

4.2.1 Number of productive tillers (mrl) of wheat

The data on number of productive tillers is presented in Table 4.12. Among fertilizer levels; the pooled data as well as individual year data indicate significantly higher number of productive tillers (69.6) with application of RDF which was statistically similar to the application of 110 % RDF (68.8). Significantly less mean number of productive tillers was observed with the application of 120 % RDF (64.8) in comparison to RDF and 110 % RDF.

Weed free check (81.6) and application of pinoxaden @ 50 g ha^{-1} (81.2) recorded significantly higher mean productive tillers compared to rest of the wild oat management treatments but were statistically at par with each other (Table 4.12). Significantly

Table 4.10: Crop growth rate (g m^{-2}day^{-1}) of wheat at 30, 60 and 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS				60 DAS												90 DAS											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	M_2	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	43	44	46	**44**	311	307	270	296	383	373	333	363	347	340	302	**330**	625	619	583	609	739	738	712	730	682	678	648	**669**
W_2	44	40	42	**42**	282	282	247	270	343	330	295	323	313	306	271	**296**	601	601	558	587	717	719	706	714	659	660	632	**650**
W_3	40	44	43	**42**	335	338	350	341	422	425	424	424	379	381	387	**382**	657	654	655	655	741	739	744	741	699	696	699	**698**
W_4	44	44	44	**44**	242	236	209	229	282	267	239	263	262	252	224	**246**	539	531	640	570	638	636	602	625	589	583	621	**579**
W_5	44	41	41	**42**	235	235	210	226	275	266	240	260	255	251	225	**243**	535	532	430	499	640	639	601	627	588	586	516	**563**
W_6	47	45	42	**45**	255	252	230	246	320	315	261	299	288	284	245	**272**	559	767	698	675	684	679	709	691	622	723	704	**683**
W_7	46	44	43	**45**	330	342	347	340	425	429	433	429	377	385	390	**384**	655	654	655	655	745	742	750	746	700	698	703	**700**
W_8	42	40	44	**42**	220	212	189	207	233	232	200	222	226	222	195	**214**	660	342	305	436	604	591	554	583	632	467	429	**509**
Mean	**44**	**43**	**43**	-	276	275	256	-	335	330	303	-	**306**	**303**	**280**	-	604	588	566	-	688	685	672	-	**646**	**636**	**619**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	1		**NS**		1		4		2		9		1		**6**		9		NS		6		NS		2		**11**	
W	1		**NS**		3		9		4		11		2		**7**		17		48		7		21		10		**18**	
W at F	2		**NS**		6		16		7		19		4		**12**		29		83		13		NS		17		**49**	
F X W	2		**NS**		5		15		7		19		4		**12**		29		82		14		NS		16		**46**	

Table 4.11: Crop growth rate (g $m^{-2}day^{-1}$) of wheat at 120 DAS and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	120 DAS												At harvest											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	397	399	366	387	271	269	287	275	334	334	326	**331**	162	161	212	178	182	177	171	177	172	169	191	**177**
W_2	367	368	364	366	281	291	281	284	324	330	322	**325**	202	192	220	205	176	172	183	177	189	182	202	**191**
W_3	405	400	397	401	302	300	304	302	353	350	350	**351**	161	173	187	174	172	178	175	175	166	175	181	**174**
W_4	381	385	242	336	323	331	324	326	352	358	283	**331**	193	187	197	192	192	193	190	192	192	190	194	**192**
W_5	387	385	442	405	322	322	327	324	355	353	385	**289**	193	186	200	193	193	196	186	192	193	191	193	**192**
W_6	388	173	191	251	286	297	251	278	337	235	221	**264**	218	216	223	219	178	173	197	183	198	194	210	**201**
W_7	395	396	398	396	294	300	301	298	344	348	350	**347**	175	178	189	181	172	174	171	172	174	176	180	**177**
W_8	215	529	518	421	359	370	370	367	287	450	444	**243**	201	200	187	196	188	182	192	188	195	191	189	**192**
Mean	367	379	365	-	304	310	306	-	**336**	**345**	**335**	-	188	187	202	-	182	181	183	-	**185**	**184**	**192**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	13		NS		6		NS		5		**NS**		4		NS		3		NS		2		**NS**	
W	18		50		8		24		10		**28**		16.81		NS		3		10		13.61		**NS**	
W at F	31		87		14		NS		17		**48**		12		NS		6		NS		6		**NS**	
F X W	32		90		15		NS		16		**47**		12		NS		6		NS		6		**NS**	

lower number of productive tillers was recorded in weedy check (53.5) followed by pendimethalin @ 1.5 kg ha^{-1} (59.2) and metribuzin @ 175 g ha^{-1} (59.8). Clodinafop @ 60 g ha^{-1} recorded significantly higher number of productive tillers (72.8) as when compared with sulfosulfuron @ 25 g ha^{-1} (69.03) but was significantly lower than the pinoxaden @ 50 g ha^{-1}. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} produced significantly higher number productive tillers as compared to pendimethalin @ 1.5 kg ha^{-1} alone to the tune of 9.62 % (Table 4.12)

The interaction between fertilizer levels and weed management treatments was significant with respect to number of productive tillers of wheat (Table. 4.12). Application of 120 % RDF with weed free situation resulted in significantly higher number of productive tillers of wheat (82.82) compared to all other treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3 which were at par with each other. Significantly less productive tillers was recorded with the combination of 120% RDF + weedy check (49.38) compared to rest of the treatment combinations. Weed free and pinoxaden @ 50 g ha^{-1} produced statistically same number of productive tillers at all the fertilizer levels. Except with pinoxaden and weed free, productive tillers in all treatment combinations decreased with increased dosage of fertilizers.

4.2.2 Spike length (cm)

Pooled data and individual year data indicate that application of 100 % RDF produced significantly longer mean spike length (8.77 cm) compared to 120 % RDF (8.57 cm), but RDF was at par with 110 % RDF (8.74 cm) (Table. 4.12) RDF produced 0.34 and 2.33 % longer spikes as compared to 110 and 120 % RDF, respectively.

Weed free (9.3 cm) and pinoxaden @ 50 g ha^{-1} (9.30 cm) being at par with each other recorded significantly longer spike as compared to rest of the wild oat management treatments during both the years of experimentation as well as in pooled data (Table 4.12). Significantly shorter spike length was noticed in weedy check (8.13 cm) followed by pendimethalin @ 1.5 kg ha^{-1} (8.31cm) and metribuzin @ 175 g ha^{-1} (8.33 cm). Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly shorter spike (8.50 cm) when compared with sulfosulfuron @ 25 g ha^{-1} (8.69 cm), whereas, clodinafop @ 60 g ha^{-1} recorded significantly longer spike (8.94 cm) when compared with sulfosulfuron @ 25 g ha^{-1}, though it was significantly shorter than the pinoxaden @ 50 g ha^{-1} and weed free.

Significant interactive effect of fertilizer levels and wild oat management treatments in respect to spike length of wheat was recorded (Table. 4.12). Significantly shorter spike length was recorded with the combination of 120 % RDF in weedy check (7.94 cm) compared to rest of treatment combinations.

Table 4.12: Productive tillers per m.r.l and spike length (cm) of wheat at maturity as Influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Productive tillers (m.r.l)												Spike length (cm)											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	73.5	72.2	65.1	70.3	78.2	77.1	71.1	75.5	75.9	74.7	68.1	**72.9**	8.92	8.91	8.60	8.81	9.13	9.12	8.96	9.07	9.02	9.02	8.78	**8.94**
W_2	68.8	67.5	61.1	65.8	75.0	73.5	68.3	72.3	71.9	70.5	64.7	**69.0**	8.74	8.72	8.40	8.62	8.82	8.78	8.67	8.76	8.78	8.75	8.53	**8.69**
W_3	78.8	79.3	80.9	79.6	82.2	82.5	83.4	82.7	80.5	80.9	82.1	**81.2**	9.12	9.26	9.28	9.22	9.29	9.37	9.42	9.36	9.21	9.32	9.35	**9.29**
W_4	57.9	56.4	49.7	54.7	67.3	65.2	62.6	65.0	62.6	60.8	56.2	**59.8**	8.41	8.33	8.09	8.28	8.56	8.46	8.11	8.38	8.49	8.40	8.10	**8.33**
W_5	56.9	55.5	49.0	53.8	67.0	65.0	61.6	64.5	62.0	60.2	55.3	**59.2**	8.40	8.32	8.09	8.27	8.54	8.46	8.09	8.36	8.47	8.39	8.09	**8.32**
W_6	62.3	61.0	55.0	59.4	73.1	73.0	65.0	70.4	67.7	67.0	60.0	**64.9**	8.54	8.42	8.20	8.39	8.70	8.67	8.44	8.60	8.62	8.54	8.32	**8.50**
W_7	79.1	79.8	81.3	80.1	82.4	82.9	84.3	83.2	80.7	81.3	82.8	**81.6**	9.21	9.27	9.35	9.28	9.32	9.35	9.44	9.37	9.27	9.31	9.40	**9.32**
W_8	50.2	49.7	43.7	47.8	61.7	60.7	55.1	59.2	55.9	55.2	49.4	**53.5**	8.22	8.21	7.86	8.10	8.24	8.22	8.01	8.16	8.23	8.22	7.94	**8.13**
Mean	65.9	65.2	60.7	-	73.3	72.5	68.9	-	**69.6**	**68.8**	**64.8**	-	8.69	8.68	8.48	-	8.83	8.80	8.64	-	**8.76**	**8.74**	**8.56**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.8		3.0		0.3		1.1		0.4		**1.4**		0.01		0.04		0.02		0.10		0.01		**0.03**	
W	0.9		2.6		0.6		1.6		0.5		**1.4**		0.02		0.06		0.03		0.08		0.02		**0.05**	
W at F	1.6		4.5		1.0		2.9		0.8		**2.4**		0.03		0.10		0.05		0.14		0.03		**0.08**	
F X W	1.7		4.7		1.0		2.8		0.9		**2.5**		0.03		0.10		0.05		0.15		0.03		**0.08**	

Application of 120 % RDF with weed free (F_3W_7) situation (9.40 cm) and pinoxaden @ 50 g ha^{-1} F_3W_3 resulted in significantly longer spike of wheat (9.38 cm) compared to all other treatment combinations. $F_2W_{7,}$ $F_1W_{7,}$ F_2W_3 and F_1W_3 resulted in significantly lower than the F_3W_7 and F_3W_3 though higher than rest of the treatment combinations.

4.2.3 Number of grains spike^{-1}

The data on number of grains per spike are presented in Table 4.13. Application of RDF resulted in significantly higher pooled mean number of grains spike^{-1} (43.1) compared to 120 % RDF (39.8), but was at par with 110 % RDF (42.9). Higher fertilizer doses *i.e.* 120 % RDF and 110 % RDF thus produced 7.46 and 0.48 % less number of grains spike^{-1}, respectively than RDF.

Weedy check produced significantly lower grains spike^{-1} as compared to rest of weed control treatments followed by pendimethalin @ 1.5 kg ha^{-1} (40.06) and metribuzin @ 175 g ha^{-1} (40.23). Pendimethalin, metribuzin, pendimethalin + metribuzin recorded significantly lower number of grains spike^{-1} (40.9) when compared with sulfosulfuron @ 25 g ha^{-1} (42.0) whereas clodinafop @ 60 g ha^{-1} recorded significantly higher number of grains/spike (43.32) when compared with sulfosulfuron @ 25 g ha^{-1}, Pendimethalin, metribuzin, pendimethalin + metribuzin but was significantly lower than the pinoxaden @ 50 g ha^{-1} and weed free. Weed free check (45.48) and application of pinoxaden @ 50 g ha^{-1} (45.34) recorded significantly higher number of grains spike^{-1} compared to all other treatments but were statistically at par with each other. Pendimethalin + metribuzin 1.5 kg ha^{-1} produced 1.99 % higher number of grains/spike as compared to alone application of pendimethalin @ 1.5 kg ha^{-1} .

The interaction between fertilizer levels and weed management treatments was significant with respect to number of grains spike^{-1} of wheat (Table. 4.13). Significantly lower number of grains spike^{-1} was recorded with the combination of 120 % RDF + weedy check (34.8) compared to rest of the treatments. Weed free with 120 % RDF *i.e.,* F_3W_7 (46.1) and, pinoxaden @ 50 g ha^{-1} (F_3W_3) resulted in significantly higher number of grains spike^{-1} of wheat (45.8) compared to all other treatment combinations. Treatment combinations *viz.* $F_2W_{7,}$ $F_1W_{7,}$ F_2W_3 and F_1W_3 are significantly lower than F_3W_7 and F_3W_3 but higher than rest of treatment combinations.

Table 4.13: Grains spike^{-1} and spikelets spike^{-1} of wheat as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Number of grains spike^{-1}												Number of spikelets spike^{-1}											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	43.3	43.2	41.2	42.6	45.2	45.0	42.0	44.1	44.3	44.1	41.6	**43.3**	18.94	18.84	16.84	18.21	22.26	22.11	19.11	21.16	20.60	20.47	17.98	**19.68**
W_2	42.4	42.1	39.0	41.2	44.2	44.0	40.2	42.8	43.3	43.1	39.6	**42.0**	18.54	18.44	16.52	17.83	21.30	21.22	18.22	20.24	19.92	19.83	17.37	**19.04**
W_3	44.4	44.4	45.4	44.7	45.8	45.9	46.1	45.9	45.1	45.2	45.7	**45.3**	19.51	19.62	20.52	19.88	23.25	23.55	23.81	23.54	21.38	21.58	22.17	**21.71**
W_4	41.5	41.4	36.6	39.8	42.5	42.2	37.2	40.6	42.0	41.8	36.9	**40.2**	17.55	17.42	15.77	16.91	19.66	19.48	16.78	18.64	18.60	18.45	16.27	**17.78**
W_5	41.5	41.2	36.3	39.6	42.4	42.0	37.0	40.5	41.9	41.6	36.6	**40.1**	17.44	17.41	15.33	16.73	19.55	19.11	16.15	18.27	18.50	18.26	15.74	**17.57**
W_6	42.0	41.9	37.8	40.5	42.8	42.5	38.2	41.2	42.4	42.2	38.0	**40.9**	17.99	17.72	16.12	17.28	20.88	20.45	17.40	19.58	19.44	19.09	16.76	**18.43**
W_7	44.5	43.9	45.8	44.7	45.9	46.0	46.4	46.1	45.2	44.9	46.1	**45.4**	19.74	19.92	20.77	20.14	23.59	23.84	23.99	23.81	21.67	21.88	22.38	**21.98**
W_8	40.8	40.6	35.2	38.9	40.2	40.0	34.0	38.1	40.5	40.3	34.6	**38.5**	16.74	16.63	15.51	16.29	17.29	17.15	15.70	16.71	17.02	16.89	15.61	**16.50**
Mean	42.5	42.3	39.6	-	43.6	43.5	40.1	-	**43.1**	**42.9**	**39.9**	-	18.31	18.25	17.17	-	20.97	20.86	18.90	-	**19.64**	**19.56**	**18.03**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.23		0.91		0.29		1.15		0.10		**0.41**		0.16		0.62		0.06		0.22		0.10		**0.40**	
W	0.28		0.79		0.39		1.10		0.19		**0.54**		0.23		0.65		0.12		0.35		0.11		**0.32**	
W at F	0.48		1.37		0.67		1.91		0.33		**0.94**		0.39		1.13		0.21		0.61		0.20		**0.56**	
F X W	0.51		1.45		0.69		1.98		0.32		**0.93**		0.40		1.14		0.21		0.60		0.21		**0.60**	

4.2.4 Number of spikelets spike^{-1}

The data on number of spikelets spike^{-1} are presented in Table 4.13. Application of RDF resulted in significantly higher mean number of and spikelets spike^{-1} (19.64) compared to 120 % RDF (18.03), but was at par with 110 % RDF (19.56). Higher fertilizer doses *i.e.*120 % and 110 % RDF resulted in 8.19 and 0.40 % lesser number of spikelets spike^{-1}, respectively over RDF.

Weed check produced significantly lower mean number of spikelets spike^{-1} as compared to rest of weed control treatments followed by pendimethalin @ 1.5 kg ha^{-1} (17.50) and metribuzin @ 175 g ha^{-1} (17.78) and pendimethalin + metribuzin @1.5 kg ha^{-1} recorded significantly lower number of spikelets spike^{-1} (40.86) when compared with sulfosulfuron @ 25 g ha^{-1} (19.04) whereas, clodinafop @ 60 g ha^{-1} recorded significantly higher number of spikelets spike^{-1} (19.68) than sulfosulfuron @ 25 g ha^{-1}, Pendimethalin, metribuzin, pendimethalin + metribuzin, and weedy check was significantly lower than the pinoxaden @ 50 g ha^{-1} and weed free. Weed free check (21.98) and application of pinoxaden @ 50 g ha^{-1} (21.71) recorded significantly higher number of spikelets spike^{-1} compared to all other treatments but were statistically at par with each other, among the wild oat management treatments. Pendimethalin + metribuzin 1.5 kg ha^{-1} produced 4.66 % higher number of spikelets spike^{-1} as compared to alone application of pendimethalin @ 1.5 kg ha^{-1} .

The interaction between fertilizer levels and weed management treatments was significant with respect to number of spikelets spike^{-1} of wheat (Table. 4.13). Among different treatment combinations significantly lower number of spikelets spike^{-1} were recorded with the combination of 120 % RDF + weedy check (15.61) compared to rest of the treatments followed by 110 % RDF + weedy check (16.89) and weedy check in RDF (17.02). Weed free with 120 % RDF *i.e.,* F_3W_7 (22.38) and F_3W_3 *i.e.,* pinoxaden @ 50 g ha^{-1} resulted in significantly higher number of spikelets spike^{-1} of wheat (22.17) compared to all other treatment combinations. Treatment combinations *viz.,* F_2W_7, F_1W_7, F_2W_3 and F_1W_3 are significantly lower number of spikelets spike^{-1} than the F_3W_7 and F_3W_3 but higher than rest of treatment combinations.

4.2.5 Test weight

Fertilizer levels and wild oat management treatments failed to cause significant difference in test weight of wheat (Table. 4.14).

4.2.6 Biological yield

Table 4.14 revealed that among fertilizer levels, the pooled data indicate significantly higher mean biological yield (112 q ha^{-1}) was obtained with the application of RDF over 120 % RDF (101 q ha^{-1}). However, biological yield with 110 % RDF (110 q ha^{-1}) was at par with RDF (112 q ha^{-1}).

Table 4.14: Test weight (g) and biological yield (q ha^{-1}) of wheat as influenced by fertilizer levels and wild oat management treatments

WMT	Test weight (g)												Biological yield (q ha^{-1})											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	43.2	43.1	41.2	42.5	44.1	44.1	42.7	43.6	43.7	43.6	41.9	**43.1**	117	113	96	109	129	129	115	124	123	121	106	**117**
W_2	42.5	42.1	40.3	41.6	43.5	43.1	41.2	42.6	43.0	42.6	40.8	**42.1**	108	106	88	101	123	121	107	117	116	113	98	**109**
W_3	43.9	43.7	43.7	43.8	44.8	44.9	45.0	44.9	44.3	44.3	44.3	**43.3**	125	126	133	128	136	138	143	139	130	132	138	**133**
W_4	41.5	40.2	38.5	40.1	42.5	41.6	39.2	41.1	42.0	40.9	38.8	**40.6**	91	90	76	86	109	102	91	101	100	96	83	**93**
W_5	41.1	40.1	38.2	39.8	42.1	41.1	39.1	40.7	41.6	40.6	38.6	**40.3**	92	87	76	85	106	101	89	98	99	94	82	**92**
W_6	42.0	41.2	39.6	40.9	43.0	42.1	40.3	41.8	42.5	41.7	40.0	**41.4**	100	97	83	93	116	114	98	109	108	105	91	**101**
W_7	43.3	43.6	43.8	43.6	44.8	44.9	45.0	44.9	44.1	44.3	44.4	**43.2**	126	127	134	129	137	138	144	140	132	132	139	**134**
W_8	40.2	39.2	37.1	38.8	41.1	40.2	38.1	39.8	40.7	39.7	37.6	**39.3**	85	81	69	78	98	93	80	90	91	87	74	**84**
Mean	42.2	41.6	40.3	-	43.2	42.7	41.3	-	**42.7**	**42.2**	**41.8**	-	105	103	95	-	119	117	108	-	**112**	**110**	**101**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.12		0.47		0.12		0.47		0.20		**NS**		0.8		3.1		1.0		3.9		0.6		**2.4**	
W	0.22		0.62		0.18		0.51		0.26		**NS**		1.7		4.9		1.2		3.3		1.2		**3.4**	
W at F	0.37		1.07		0.31		0.89		0.77		**NS**		3.0		8.5		2.0		5.7		2.1		**5.9**	
F X W	0.37		1.06		0.32		0.90		0.77		**NS**		2.9		8.3		2.1		6.1		2.0		**5.8**	

Application of pinoxaden @ 50 g ha^{-1} (133 q ha^{-1}) and weed free check (134 q ha^{-1}) produced significantly higher biological yield as compared to rest of the herbicide treatments, but were statistically at par with each other. Clodinafop @ 60 g ha^{-1} recorded significantly higher biological yield (117 q ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (109 q ha^{-1}) but these two herbicide product were significantly lower than the pinoxaden @ 50 g ha^{-1}, among different wild oat management treatments. Pendimethalin @ 1.5 kg ha^{-1} (92 q ha^{-1}) and metribuzin @ 175 g ha^{-1} (93 q ha^{-1}) produced significantly lower biological yield to the tune of 8.91 and 7.92 % when these treatments were compared with pendimethalin + metribuzin @ 1.5 kg $ha^{-1)}$ (101 q ha^{-1}). Significantly lowest biological yield resulted from weedy check (84 q ha^{-1}) which was 37.3 % of lower than weed free treatment.

The interaction effect between fertilizer levels and weed management was significant with respect to biological yield of wheat (Table. 4.14). Application of 120 % RDF with weed free situation *i.e.,* F_3W_7 resulted in significantly higher mean biological yield of wheat (139 q ha^{-1}) as compared rest of the treatment combinations except $F_3W_{3.}$ $F_2W_{7,}$ $F_1W_{7,}$ F_2W_3 and F_1W_3 which were at par with each other. Significantly less biological yield was recorded with the combination of 120 % RDF + weedy check (74 q ha^{-1}) as compared to rest of the treatment combinations.

4.2.7 Grain yield (q ha^{-1})

Grain yield of wheat varied significantly due to fertilizer levels and wild oat management treatments in wheat (Table 4.15). The pooled analysis and individual year of data revealed that significantly higher mean grain yield (44.7 q ha^{-1}) was recorded in RDF which was statistically at par with the application of 110 % RDF (43.5 q ha^{-1}). Significantly lower grain yield was recorded with the application of 120 % RDF (40.2 q ha^{-1}) than RDF and thus 110 % RDF. RDF produced 2.7 and 11.2 % higher wheat grain yield as compared with 110 % and 120 % RDF treatment, significantly.

Weed free produced the highest mean grain yield (55.3 q ha^{-1}), whereas, weedy condition produced the lowest wheat grain yield which was to the tune of 56.6 %, among different wild oat management treatment (Table. 4.15). Application of pinoxaden @ 50 g ha^{-1} (54.8 q ha^{-1}) produced significantly higher grain yield as compared to rest of the treatments. Clodinafop @ 60 g ha^{-1} recorded significantly higher grain yield (46.8 q ha^{-1}) as compared with sulfosulfuron @ 25 g ha^{-1} (42.9 q ha^{-1}) though it was significantly lower than the pinoxaden @ 50g ha^{-1} (54.8 q ha^{-1}). Pendimethalin @ 1.5 kg ha^{-1} (35.2 q ha^{-1}) and metribuzin @ 175 g ha^{-1} (36.1 q ha^{-1}) produced statistically similar grain yield. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly higher grain yield as compared with pendimethalin @ 1.5 kg ha^{-1} alone (35.2 q ha^{-1}) and metribuzin @ 175 g ha^{-1} (36.1 q ha^{-1}). Where as pendimethalin and metribuzin were at par with each other.

The interaction between fertilizer levels and wild oat management treatment was significant with respect to grain yield of wheat (Table. 4.15). Treatment combination F_3W_7 *i.e*., application of 120 % RDF + weed free resulted in significantly higher grain yield of wheat (56.92 q ha^{-1}) compared to rest of treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3, however, these combinations also produced statistically similar grain yield with each other. Significantly lower grain yield was recorded with the combination of 120 % RDF + weedy check (27.5 q ha^{-1}) as compared with rest of treatments. Weed free and pinoxaden @ 50 g ha^{-1} produced statistically same amount of grain yield at all the fertilizer levels. Irrespective of fertilizer levels clodinafop @ 60 g ha^{-1} produced significantly higher grain yield as compared to pendimethalin @ 1.5 kg ha^{-1}, however, clodinafop or Pendimethalin + RDF produced significantly higher grain yield as compared to the same herbicide at 120 % RDF.

4.2.8 Straw yield (q ha^{-1})

Significantly lower mean straw yield was observed with the application of 120 % RDF (61.2 q ha^{-1}) whereas significantly higher straw yield was with RDF (67.6 q ha^{-1}) which at par with the application of 110 % RDF (66.5 q ha^{-1}) (Table. 4.15).

Significantly lower straw yield was noticed in weedy check (52.9 q ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (56.7 q ha^{-1}) and metribuzin @ 175 g ha^{-1} (57.1 q ha^{-1}), among the wild oat management treatments. Clodinafop @ 60 g ha^{-1} recorded significantly higher straw yield (69.7 q ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (66.1 q ha^{-1}), pendimethalin, metribuzin, pendimethalin + metribuzin and weedy check but was significantly lower than pinoxaden. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly higher straw yield (61.4 q ha^{-1}) when it was compared with pendimethalin @ 1.5 kg ha^{-1} (56.7 q ha^{-1}) and metribuzin @ 175 g ha^{-1} (57.1 q ha^{-1}). Weed free check (79.1 q ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (78.6) recorded significantly higher straw yield compared to rest of the treatments, though were statistically at par with each other.

The interaction between fertilizer levels and wild oat management treatments, differ significantly with respect to straw yield of wheat (Table 4.15). Significantly lower straw yield was recorded with the combination of 120 % RDF in weedy check (46.9 q ha^{-1}) compared to all other treatment combinations, application of 110 % RDF in weedy check (54.7 q ha^{-1}) and weedy check in RDF (56.9 q ha^{-1}), RDF and 110 % RDF show at par relation with each other though significantly higher than the 120 % RDF with weedy check.

Table 4.15: Grain yield and straw yield of wheat as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Grain yield (q ha^{-1})												Straw yield (q ha^{-1})											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	47.6	45.0	39.3	44.0	52.5	51.4	45.0	49.7	50.1	48.2	42.2	**46.8**	69.3	68.2	57.0	64.8	76.7	77.3	70.1	74.7	73.0	72.7	63.5	**69.7**
W_2	42.4	41.3	34.6	39.4	49.1	47.8	42.5	46.5	45.8	44.5	38.5	**42.9**	65.8	64.7	53.8	61.4	74.0	73.0	64.9	70.6	69.9	68.8	59.4	**66.0**
W_3	51.6	51.9	54.7	52.8	55.6	56.8	58.2	56.9	53.6	54.4	56.5	**54.8**	73.2	74.1	78.5	75.3	80.0	80.9	85.0	82.0	76.6	77.5	81.7	**78.6**
W_4	35.6	34.2	29.7	33.2	42.6	39.5	35.1	39.0	39.1	36.8	32.4	**36.1**	55.6	55.4	46.4	52.5	66.4	63.0	55.6	61.7	61.0	59.2	51.0	**57.1**
W_5	35.2	33.2	29.5	32.7	40.5	38.7	34.4	37.8	37.9	35.9	31.9	**35.2**	56.4	53.7	46.4	52.2	65.3	62.0	54.2	60.5	60.9	57.9	50.3	**56.7**
W_6	39.0	37.9	32.6	36.5	46.6	45.1	39.0	43.6	42.8	41.5	35.8	**40.0**	61.2	58.8	50.6	56.9	69.9	68.6	59.1	65.8	65.6	63.7	54.8	**61.4**
W_7	52.2	52.5	55.0	53.3	56.6	56.7	58.8	57.3	54.4	54.6	56.9	**55.3**	73.9	74.4	79.3	75.9	80.5	81.1	85.2	82.3	77.2	77.7	82.3	**79.1**
W_8	32.6	29.9	25.8	29.4	35.8	34.7	29.2	33.2	34.2	32.3	27.5	**31.3**	52.1	50.9	42.8	48.6	61.8	58.5	51.0	57.1	56.9	54.7	46.9	**52.9**
Mean	42.0	40.7	37.7	-	47.4	46.3	42.8	-	**44.7**	**43.5**	**40.2**	-	63.4	62.5	56.9	-	71.8	70.5	65.6	-	**67.6**	**66.5**	**61.2**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.6		2.2		0.8		3.1		0.4		**1.6**		0.7		2.7		0.8		3.1		0.6		**2.3**	
W	0.9		2.5		0.9		2.5		0.7		**2.1**		1.0		2.9		0.9		2.6		0.7		**1.9**	
W at F	1.5		4.3		1.5		4.3		1.3		**3.6**		1.8		5.0		1.6		4.5		1.2		**3.3**	
F X W	1.5		4.4		1.6		4.6		1.2		**3.6**		1.8		5.1		1.7		4.8		1.2		**3.5**	

Significantly higher straw yield was recorded with weed free check (82.2 q ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (81.7 q ha^{-1}) but were statistically at par with each other. Treatment combinations *viz.,* F_2W_7, F_1W_7, F_2W_3 and F_1W_3 had significantly higher straw yield than rest of the treatment combinations but statistically at par with each other though lower than the F_3W_3, F_3W_7. In all other weed management treatments straw yield decreased with increase in dose of nitrogen.

4.3 Wild oat observation in field

The data on wild oat *viz.,* wild oat density, wild oat dry weight, weed control efficiency, days to 50 % spike emergence, days to 50 % flowering of wild oat, panicle length, seeds per panicle and test weight of wild oat seeds as influenced by fertilizer levels and wild oat management in wheat are presented in Tables 4.16 to 4.24

4.3.1 Wild oat density

Wild oat density varied significantly due to fertilizers levels and wild oat management treatments at all growth stages except at 30 DAS (Tables 4.16 and 4.17). At, 60, 90, 120 DAS and at harvest; pooled data revealed that in significantly higher wild oat density was recorded with 120 % RDF *i.e.,* (55.2, 54.0, 56.3 and 51.9 at 60, 90,120 DAS and at harvest, respectively) as compared to RDF (42.4, 40.1, 40.9 and 39.8 at 60, 90, 120 DAS and at harvest, respectively), however, RDF was statistically at par with 110 % RDF (45.1, 43.1, 44.1 and 42.3 at 60, 90, 120 DAS and at harvest, respectively).

Among the wild oat management treatments, weed free (3.2, 2.7, 3.01 and 2.7, respectively) and pinoxaden @ 50 g ha^{-1} (3.5, 3.7, 4.8 and 4.01, respectively) being at par with each other produced significantly lower wild oat density as compared to rest of the wild oat management treatments during both the years as well as in pooled data at all the growth stages of the crop except at 30 DAS which resulted in non-significant difference among all wild oat management treatments. Significantly higher wild oat density was recorded in weedy check (113.4, 109.1, 112 and 109) followed by pendimethalin @ 1.5 kg ha^{-1} (82.4, 79.2, 81.1 and 76.5, respectively) and metribuzin @ 175 g ha^{-1} (71.2, 68.4, 69.9 and 65.6, respectively) at 60, 90, 120 DAS and at harvest, respectively. pendimethalin, metribuzin, pendimethalin + metribuzin @ (1.5 kg ha^{-1}) recorded significantly higher wild oat density *i.e.,* 49.3, 47.1, 50.3 and 46.1 when compared with sulfosulfuron @ 25 g ha^{-1} (41.9, 40.5, 40.5) and 38.9 at 60, 90, 120 DAS and at harvest, whereas, clodinafop @ 60 g ha^{-1} recorded significantly lower wild oat density (15.3, 14.7, 15.5 and 14.3) Than all other treatment except pinoxaden @ 50 g ha^{-1} and weed free conditions.

Table 4.16: Wild oat density (No. m^{-2}) at 30, 60 & 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS				60 DAS												90 DAS											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**M_2**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	32.5	32.4	32.5	**32.5**	8.3	10.0	21.7	13.3	13.0	14.7	24.3	17.3	10.7	12.3	23.0	**15.3**	9.0	10.0	22.3	13.8	10.3	12.7	23.7	15.6	9.7	11.3	23.0	**14.7**
W_2	33.0	33.5	32.4	**33.0**	30.7	33.3	48.7	37.6	39.0	43.0	57.0	46.3	34.8	38.2	52.8	**41.9**	29.0	32.0	46.3	35.8	37.0	41.3	57.3	45.2	33.0	36.7	51.8	**40.5**
W_3	33.0	33.3	33.7	**33.3**	2.0	2.3	2.7	2.3	4.3	4.7	5.0	4.7	3.2	3.5	3.8	**3.5**	3.0	3.7	4.0	3.6	3.3	3.7	4.3	3.8	3.2	3.7	4.2	**3.7**
W_4	33.2	34.2	33.9	**33.8**	56.7	61.0	79.3	65.7	67.7	73.3	89.7	76.9	62.2	67.2	84.5	**71.3**	54.0	58.0	75.0	62.3	64.0	70.7	89.0	74.6	59.0	64.3	82.0	**68.4**
W_5	32.8	32.8	34.0	**33.2**	64.7	71.0	88.3	74.7	82.7	86.7	101	90.2	73.7	78.8	94.8	**82.4**	62.0	67.0	85.0	71.3	77.0	84.7	100	87.2	69.5	75.8	92.5	**79.3**
W_6	32.0	33.7	32.7	**32.8**	36.3	41.0	55.3	44.2	46.3	50.7	66.0	54.3	41.3	45.8	60.7	**49.3**	34.3	39.0	53.0	42.1	42.7	48.3	65.0	52.0	38.5	43.7	59.0	**47.1**
W_7	31.7	32.8	34.4	**32.9**	1.7	2.0	2.3	2.0	4.0	4.3	4.7	4.3	2.8	3.2	3.5	**3.2**	1.0	2.0	3.0	2.0	3.0	3.3	4.0	3.4	2.0	2.7	3.5	**2.7**
W_8	34.0	32.9	32.0	**33.0**	104	106	115	108	116	117	122	118	110	112	119	**113**	100	102	111	104	110	111	120	114	105	107	116	**109**
Mean	**32.8**	**33.2**	**33.2**	-	38.0	40.8	51.7	-	46.7	49.3	58.8	-	**42.4**	**45.1**	**55.2**	-	36.5	39.2	50.0	-	43.4	47.0	57.9	-	**40.0**	**43.1**	**54.0**	-
	SEm±		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**	
F	0.4		**NS**		1.1		4.1		1.2		4.5		0.7		**2.9**		1.0		4.0		1.0		4.1		0.6		**3.1**	
W	0.4		**NS**		1.7		4.8		1.5		4.4		1.2		**3.4**		1.8		5.1		1.8		5.0		1.3		**3.7**	
W at F	0.6		**NS**		2.9		8.3		2.7		7.7		2.1		**5.9**		3.1		8.9		3.0		8.7		2.2		**6.4**	
F X W	0.7		**NS**		2.9		8.3		2.8		7.9		2.1		**5.9**		3.1		8.8		3.0		8.7		2.2		**6.2**	

Table 4.17: Wild oat density (No. m^{-2}) at 120 DAS and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	120 DAS												At harvest											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	8.0	9.7	22.0	13.2	12.7	14.0	26.7	17.8	10.3	11.8	24.3	**15.5**	8.0	9.0	18.0	11.7	11.3	13.7	25.7	16.9	9.7	11.3	21.8	**14.3**
W_2	28.7	32.0	47.0	35.9	37.7	39.0	58.7	45.1	33.2	35.5	52.8	**40.5**	28.0	30.7	45.0	34.6	35.7	38.7	55.7	43.3	31.8	34.7	50.3	**38.9**
W_3	3.0	4.7	5.7	4.4	4.7	5.0	6.0	5.2	3.8	4.8	5.8	**4.8**	2.7	3.7	5.0	3.8	3.7	4.0	5.0	4.2	3.2	3.8	5.0	**4.0**
W_4	53.3	59.7	77.0	63.3	66.7	72.0	91.0	76.6	60.0	65.8	84.0	**69.9**	53.3	57.3	63.0	57.9	63.0	68.3	88.7	73.3	58.2	62.8	75.8	**65.6**
W_5	62.0	68.7	88.0	72.9	79.3	86.0	102	89.1	70.7	77.3	95.0	**81.0**	62.0	66.3	73.3	67.2	78.3	81.7	97.7	85.9	70.2	74.0	85.5	**76.5**
W_6	34.0	38.7	60.7	44.4	46.7	50.0	71.7	56.1	40.3	44.3	66.2	**50.3**	33.3	37.3	52.3	41.0	43.0	47.0	63.7	51.2	38.2	42.2	58.0	**46.1**
W_7	1.0	2.0	3.7	2.2	2.3	3.0	6.0	3.8	1.7	2.5	4.8	**3.0**	1.7	2.2	3.7	2.5	2.2	3.0	3.7	2.9	1.9	2.6	3.7	**2.7**
W_8	100	103	114	106	114	118	121	118	107	111	117	**112**	98	101	112	104	112	114	118	115	105	107	115	**109**
Mean	36.3	39.8	52.2	-	45.5	48.3	60.4	-	40.9	44.1	56.3	-	35.9	38.4	46.5	-	43.6	46.3	57.3	-	39.8	42.3	51.9	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	1.6		6.3		1.0		4.1		1.0		4.0		0.7		2.9		1.1		4.5		0.9		3.4	
W	1.5		4.3		1.8		5.0		1.1		3.3		1.4		4.1		2.0		5.8		1.2		3.4	
W at F	2.6		7.4		3.0		8.7		2.0		5.7		2.5		NS		3.5		10.0		2.1		5.9	
F X W	2.9		8.3		3.0		8.6		2.1		6.1		2.5		NS		3.5		10.0		2.1		6.0	

The interaction between fertilizer levels and wild oat management treatments was significantly differed with respect to wild oat density at 60, 90, 120 DAS and at harvest, (Table. 4.16 and 4.17). Application of 120 % RDF (F_3W_8) situation resulted in significantly more wild oat density (119, 116, 117 and 115) compared to all other treatment combinations followed by 110 % RDF with weedy check (112, 107, 111, and 107) and weedy check in RDF (110, 105, 107 and 105) also resulted in significantly higher wild oat density than all treatments at all the growth stages. Significantly less wild oat density was recorded with the combination of RDF in weed free and pinoxaden @ 50 g ha^{-1} (2.8, 2, 2.5 and 1.9) compared to all other treatments except $F_3W_{1,}$ $F_1W_{3,}$ $F_2W_{3,}$ $F_2W_{7,}$ and F_3W_7 with which it was at par.

4.3.2 Wild oat dry weight (g m^{-2})

Wild oat dry weight was influenced significantly with fertilizer levels and herbicide treatments (Tables 4.18 and 4.19). The dry matter of wild oat increased with the increase in fertilizer doses. Initially at 30 DAS no significant effect of fertilizer doses was observed but in later stages significant difference were recorded. With the increase in fertilizer dose from RDF to 120 % RDF there was significant increase in wild oat dry matter. Though 110 % RDF resulted in significantly lower dry matter than 120 % RDF but it did not differ significantly with RDF at 60 DAS and later growth stages.

Significantly higher wild oat dry weight was recorded in weedy check (243, 272, 350 and 310 g m^{-2}) than all other treatments at 60, 90, 120 DAS and at harvest, respectively pendimethalin @ 1.5 kg ha^{-1} (177, 192, 252 and 225 g m^{-2}) and metribuzin @ 175 g ha^{-1} (153, 172, 219 and 195 g m^{-2} also resulted in significantly higher dry weight wild oat than all other treatments except weedy check. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly higher wild oat dry weight (106, 116, 148 and 140 g m^{-2}) when compared with sulfosulfuron @ 25 g ha^{-1} (90, 100, 126 and 113 g m^{-2}). However, clodinafop @ 60 g ha^{-1} recorded significantly lower wild oat dry weight (33, 36, 48 and 43 g m^{-2}) when compared with sulfosulfuron @ 25 g ha^{-1}, but these were significantly higher than the pinoxaden @ 50 g ha^{-1}. Application of pinoxaden @ 50 g ha^{-1} (7.4, 9.3, 14 and 13 g m^{-2}) and weed free (6.8, 6.9, 8.1, 8.0 g m^{-2}) recorded significantly lower wild oat dry weight compared to rest of the treatments but were statistically at par with each other at 60, 90 and 120 DAS and at harvest, (Figs. 5 & 6).

Table 4.18: Wild oat dry weight (g m^{-2}) at 30, 60 and 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	30 DAS				60 DAS												90 DAS											
	Pooled				2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	M_2	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	4.2	3.9	3.4	**3.8**	18	21	47	29	28	31	52	37	23	26	50	**33**	23	25	56	35	24	31	59	38	23	28	58	**36**
W_2	3.4	3.6	4.2	**3.7**	65	71	106	81	84	93	124	100	75	82	115	**90**	73	80	118	90	90	103	139	111	81	92	129	**100**
W_3	3.8	4.1	4.1	**4.0**	4	5	6	5	9	10	11	10	7	7	8	**7.4**	7	9	10	9	9	10	10	10	8	9	10	**9.3**
W_4	4.0	3.4	3.6	**3.6**	121	130	171	141	145	157	194	166	133	144	183	**153**	135	153	191	160	158	177	221	185	147	165	206	**172**
W_5	3.0	3.2	3.3	**3.2**	138	152	192	160	177	186	219	194	158	169	205	**177**	156	170	215	180	191	177	245	204	173	173	230	**192**
W_6	2.8	3.1	3.2	**3.0**	77	88	120	95	99	109	142	117	88	98	131	**106**	85	98	135	106	106	120	151	125	95	109	143	**116**
W_7	3.2	3.3	3.7	**3.4**	4	4	5	4	9	9	10	9	6	7	8	**6.8**	3	5	8	5	8	9	10	9	5	7	9	**6.9**
W_8	3.5	3.2	3.3	**3.3**	222	226	249	232	248	251	263	254	235	238	256	**243**	250	257	282	263	272	275	296	281	261	266	289	**272**
Mean	**3.5**	**3.4**	**3.6**	-	81	87	112	-	100	106	127	-	**91**	**96**	**119**	-	91	100	127	-	107	113	141	-	**99**	**106**	**134**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.2		NS		2		8		3		12		2		**8**		2		9		4		16		2		**7**	
W	0.2		NS		4		11		4		12		3		**8**		4		11		6		16		3		**9**	
W at F	0.3		NS		6		18		7		20		5		**14**		7		20		10		28		5		**15**	
F X W	0.3		NS		6		18		7		21		5		**14**		7		20		10		28		5		**15**	

Table 4.19: Wild oat dry weight (g m^{-2}) at 120 DAS and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	120 DAS												At harvest											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	25	30	71	42	35	44	83	54	30	37	77	**48**	22	27	64	38	34	38	75	49	28	32	70	**43**
W_2	92	102	154	116	110	120	180	137	101	111	167	**126**	80	89	135	101	102	105	165	124	91	97	150	**113**
W_3	9	15	18	14	11	13	16	13	10	14	17	**14**	8	13	16	12	12	13	17	14	10	13	16	**13**
W_4	177	188	252	206	197	213	286	232	187	201	269	**219**	149	166	223	179	181	194	256	210	165	180	239	**195**
W_5	201	214	286	233	243	255	316	271	222	234	301	**252**	173	191	254	206	215	231	287	244	194	211	271	**225**
W_6	107	121	178	135	134	146	204	161	120	133	191	**148**	95	108	175	126	127	134	202	154	111	121	188	**140**
W_7	4	7	12	7	7	9	12	9	5	8	12	**8**	3	6	11	6	6	8	17	10	5	7	14	**8**
W_8	318	324	372	338	348	354	382	361	333	339	377	**350**	279	286	328	298	310	317	340	323	295	301	334	**310**
Mean	117	125	168	-	136	144	185	-	**126**	**135**	**176**	**-**	101	111	151	-	123	130	170	-	**112**	**120**	**160**	**-**
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	4		14		4		15		2		**9**		5		22		3		10		2		**8**	
W	5		14		6		17		4		**11**		5		13		5		14		3		**9**	
W at F	8		24		10		29		6		**18**		8		23		9		24		5		**16**	
F X W	9		25		10		29		6		**19**		9		27		8		24		6		**16**	

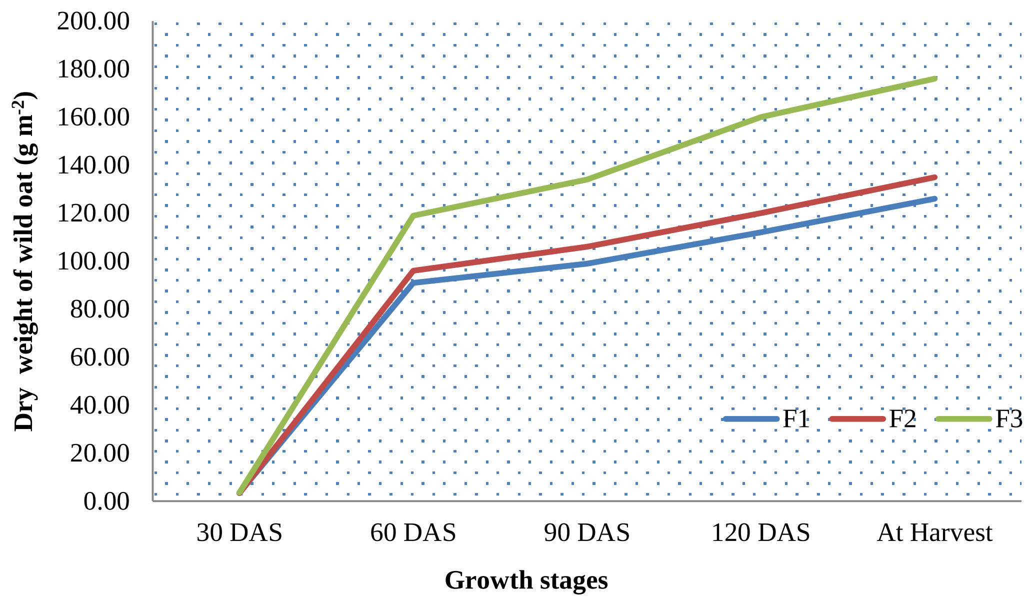


Fig. 5: Wild oat dry weight (g m^{-2}) at 30, 60, 90, 120 DAS and at harvest as influenced by fertilizer levels in wheat

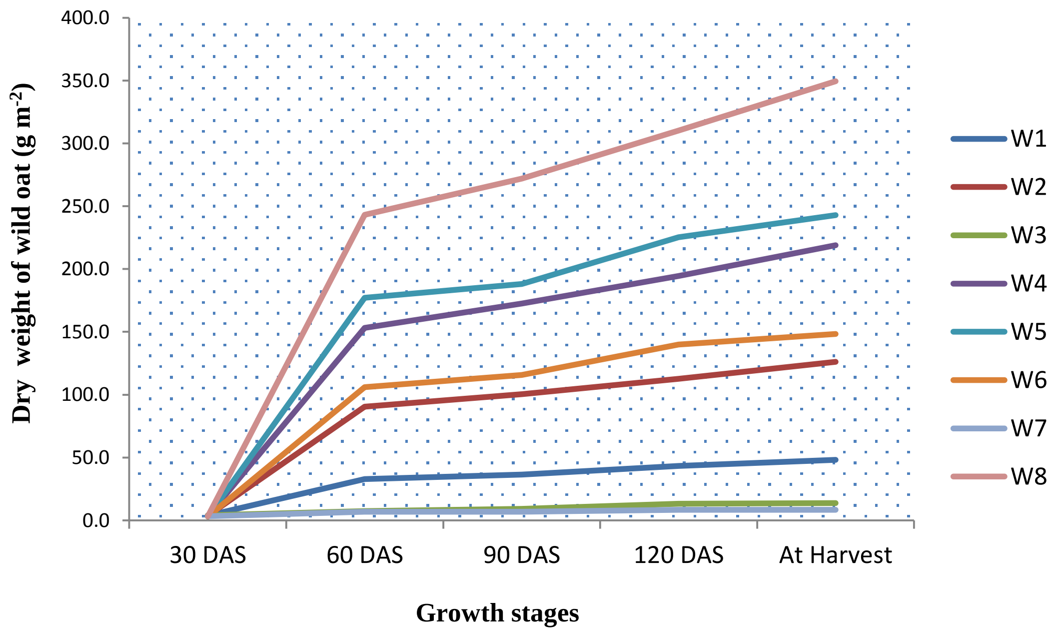


Fig. 6: Wild oat dry weight (g m^{-2}) at 30, 60, 90, 120 DAS and at harvest as influenced by wild oat management treatments in wheat

The interaction between fertilizer levels and wild oat management treatments was significant with respect to wild oat dry weight at 60, 90, 120 DAS and at harvest but non-significant at 30 DAS. With the increase in fertilizer levels dry weight of wild oat increased in weedy check and pendimethalin @ 1.5 kg ha^{-1}. However, significantly higher dry weight of wild oat was recorded in 120 % RDF as compared to RDF in both treatments beyond 60 DAS although weedy check resulted in significantly higher values than pendimethalin @ 1.5 kg ha^{-1}. No significant effect on wild oat dry weight was recorded in pinoxaden @ 50 g ha^{-1} and weed free with the increase in fertilizer levels. Pinoxaden @ 50 g ha^{-1} and clodinafop @ 60 g ha^{-1} reduced the wild oat dry weight as compared to rest of treatments. Application of 120 % RDF significantly increased wild oat dry matter as compared to RDF and 110 % RDF which were at par with each other all growth stages except with pinoxaden and weed free conditions (Table. 4.18 and 4.19, Fig 5 & 6).

4.3.3 Weed control efficiency (WCE, %)

Table 4.20 and 4.21 revealed that WCE varied significantly with fertilizer application levels and different herbicidal treatments. In general, WCE decreased with the increase in fertilizer levels. The maximum WCE was recorded in RDF, however, it was significantly at par with 110 % RDF. Application of 120 % RDF resulted in significantly lower WCE as compared to RDF and 110 % RDF.

The maximum WCE was recorded in weed free (Tables 4.20, 4.21 and Fig. 7). Among different herbicides pendimethalin @ 1.5 kg ha^{-1} resulted in lowest WCE (%), however, maximum was recorded in pinoxaden @ 50 g ha^{-1} from 60 DAS to harvest. Clodinafop @ 60 g ha^{-1} though resulted in significantly lower WCE as compared to pinoxaden @ 50 g ha^{-1} but was superior to rest of the herbicides. Pendimethalin + metribuzin (@ 1.5 kg ha^{-1}) was significantly superior in controlling wild oat as compared to metribuzin @ 175 g ha^{-1} and pendimethalin @ 1.5 kg ha^{-1}.

In general herbicides resulted in decrease in WCE at different levels of fertilizers but it was not true in case of pinoxaden @ 50 g ha^{-1} and weedy check where non-significant difference were recorded. In rest of the herbicides 120 % RDF resulted in significantly lower WCE as compared to RDF or 110 % RDF. At the same level of fertilizer clodinafop @ 60 g ha^{-1} and pinoxaden @ 50 g ha^{-1} were proved superior in controlling wild oat as compared to other herbicides. The lowest WCE was observed with being in pendimethalin @ 1.5 kg ha^{-1} at all stages of growth.

4.3.4 Days to 50 % spike emergence and flowering (%)

Among fertilizer levels, the pooled data revealed that application of 100 % RDF resulted in significantly higher number of days to attain 50 % spike emergence and flowering (98 and 106 DAS) compared to 120 % RDF (96 and 103 DAS) though, RDF was at par with

Table 4.20: Weed control efficiency at 60 and 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	60 DAS												90 DAS											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	92.5	90.2	80.0	87.5	89.4	88.0	76.3	84.5	90.9	89.1	78.1	**86.0**	92.2	90.1	79.8	87.3	90.2	88.3	78.3	85.6	91.2	89.2	79.0	**86.5**
W_2	70.7	68.6	49.0	62.8	67.6	62.6	40.8	57.0	69.2	65.6	44.9	**59.9**	71.0	68.0	47.9	62.3	67.5	64.6	41.7	57.9	69.2	66.3	44.8	**60.1**
W_3	96.7	95.1	95.0	95.6	96.3	96.1	94.8	95.7	96.5	95.6	94.9	**95.7**	97.2	95.6	95.3	96.0	97.0	96.6	95.1	96.2	97.1	96.1	95.2	**96.1**
W_4	44.4	42.4	25.3	37.3	41.8	36.6	22.9	33.8	43.1	39.5	24.1	**35.6**	44.3	42.3	25.2	37.3	42.6	35.8	23.6	34.0	43.4	39.1	24.4	**35.6**
W_5	37.8	32.6	17.1	29.2	28.5	25.4	11.9	21.9	33.1	29.0	14.5	**25.5**	37.5	33.8	17.2	29.5	28.2	24.9	12.1	21.7	32.8	29.3	14.6	**25.6**
W_6	66.4	62.4	38.1	55.7	60.0	56.4	30.7	49.0	63.2	59.4	34.4	**52.3**	66.9	63.6	38.6	56.4	61.4	57.2	29.9	49.5	64.1	60.4	34.2	**52.9**
W_7	98.9	98.1	96.6	97.9	96.4	96.3	94.5	95.7	97.6	97.2	95.6	**96.8**	99.2	96.8	96.7	97.6	97.3	96.9	95.1	96.4	98.3	96.8	95.9	**97.0**
W_8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Mean	63.4	61.2	50.1	-	60.0	57.7	46.5	-	**61.7**	**59.4**	**48.3**	**-**	63.5	61.3	50.1	-	60.5	58.0	47.0	-	**62.0**	**59.7**	**48.5**	**-**
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	1.0		4.1		2.5		9.9		1.0		**3.9**		2.5		9.9		1.8		7.1		1.4		**5.4**	
W	1.8		5.2		2.3		6.5		1.5		**4.2**		1.9		5.4		1.9		5.5		1.4		**3.9**	
W at F	3.2		9.0		3.9		11.2		2.5		**7.2**		3.3		9.3		3.3		9.5		2.4		**6.8**	
F X W	3.1		9.0		4.4		12.7		2.6		**7.3**		4.0		11.3		3.6		10.3		2.6		**7.5**	

Table 4.21: Weed control efficiency at 120 and at harvest as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	120 DAS												At harvest											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	88.9	87.1	78.1	84.7	88.6	87.9	77.1	84.6	88.8	87.5	77.6	**84.6**	92.1	90.5	77.8	86.8	89.7	87.7	78.3	85.3	90.9	89.1	78.0	**86.0**
W_2	66.0	61.5	43.8	57.1	67.0	66.6	39.7	57.7	66.5	64.0	41.7	**57.4**	71.2	67.9	48.9	62.7	67.9	66.1	41.2	58.4	69.6	67.0	45.0	**60.5**
W_3	95.0	94.7	95.8	95.2	96.0	95.6	95.4	95.7	95.5	95.2	95.6	**95.4**	96.6	96.5	96.2	96.4	96.7	96.5	95.2	96.1	96.6	96.5	95.7	**96.3**
W_4	40.9	36.7	25.3	34.3	40.7	37.9	29.6	36.0	40.8	37.3	27.5	**35.2**	45.4	42.0	24.7	37.4	43.4	39.7	22.9	35.3	44.4	40.8	23.8	**36.3**
W_5	29.3	26.8	11.2	22.4	29.7	29.6	12.4	23.9	29.5	28.2	11.8	**23.2**	32.6	31.8	16.8	27.1	29.5	28.0	12.2	23.3	31.0	29.9	14.5	**25.2**
W_6	62.4	58.0	33.7	51.4	58.9	57.1	30.2	48.8	60.7	57.6	32.0	**50.1**	63.8	62.4	39.7	55.3	61.7	58.8	30.5	50.4	62.8	60.6	35.1	**52.8**
W_7	97.3	96.8	96.0	96.7	98.0	97.3	94.8	96.7	97.6	97.0	95.4	**96.7**	98.4	98.1	97.9	98.1	98.4	98.3	95.4	97.4	98.4	98.2	96.6	**97.7**
W_8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Mean	60.0	57.7	48.0	-	59.9	59.0	47.4	-	**59.9**	**58.3**	**47.7**	-	62.5	61.2	50.2	-	60.9	59.4	47.0	-	**61.7**	**60.3**	**48.6**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	1.1		4.5		2.4		9.5		0.8		**3.3**		1.8		7.1		2.0		7.7		0.7		**2.7**	
W	2.2		6.2		2.6		7.3		1.4		**4.1**		2.1		6.1		2.1		6.0		1.5		**4.1**	
W at F	3.8		10.8		4.4		12.7		2.5		**7.0**		3.7		10.5		3.7		10.4		2.5		**7.2**	
F X W	3.7		10.6		4.8		13.7		2.4		**7.0**		3.9		11.1		3.9		11.2		2.5		**7.0**	

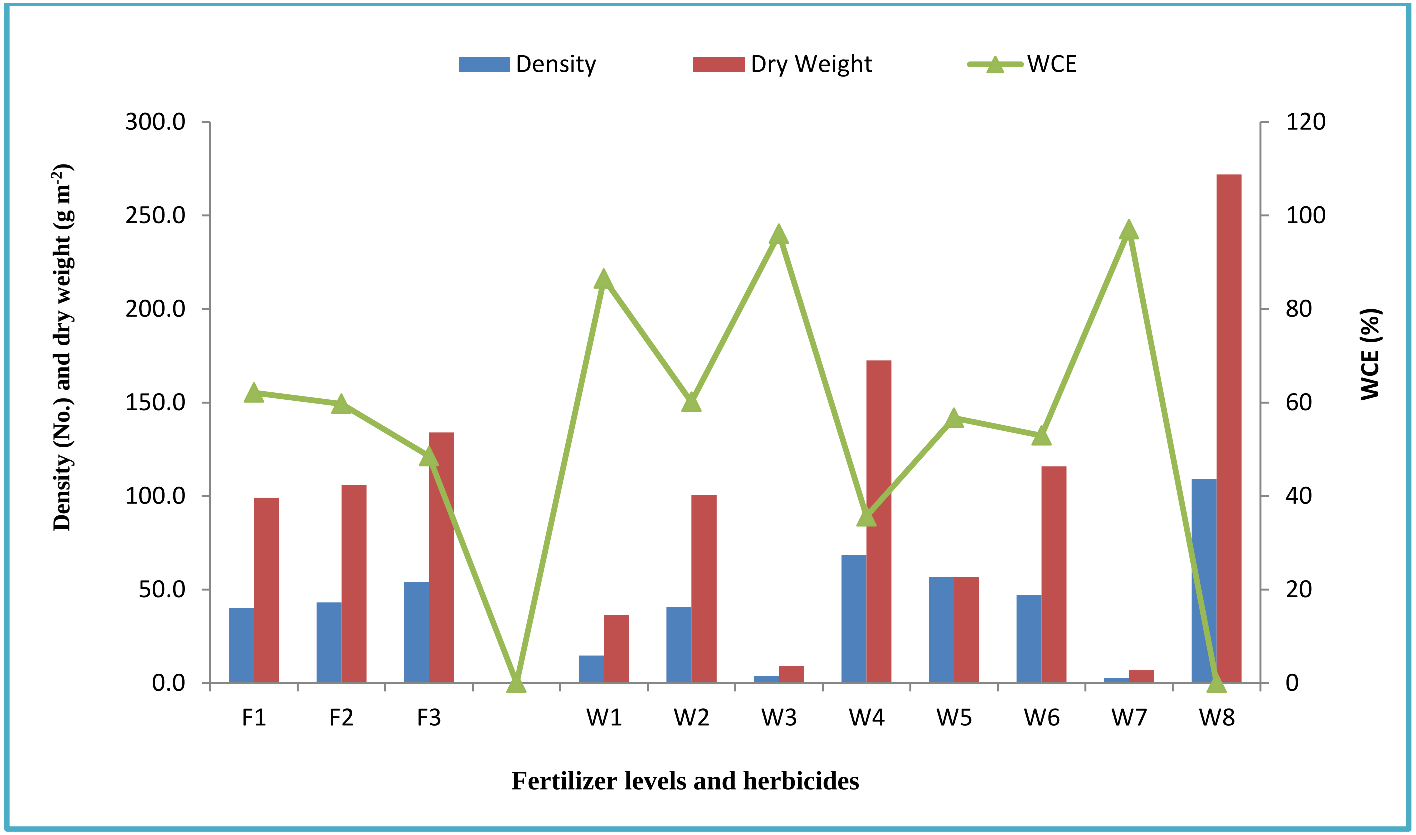


Fig. 7: Wild oat density (No. m^{-2}), dry weight (g m^{-2}) and WCE (%) at 90 DAS as influenced by fertilizer levels and wild oat management treatments in wheat

Table 4.22: Spike emergence and flowering of wild oat as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Spike emergence (DAS)												Flowering (DAS)											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	98	99	96	98	99	100	96	98	98	99	96	**98**	106	106	103	105	106	107	104	106	106	107	103	**105**
W_2	98	99	96	98	98	99	97	98	98	99	97	**98**	105	106	103	105	106	107	104	106	106	106	104	**105**
W_3	96	97	96	96	97	97	97	97	97	97	96	**97**	104	104	103	104	105	105	104	105	105	104	104	**104**
W_4	98	99	96	98	99	99	97	98	98	99	96	**98**	105	106	103	105	106	107	104	106	106	106	104	**105**
W_5	100	98	95	98	100	99	96	98	100	98	95	**98**	108	105	102	105	109	106	103	106	108	106	103	**105**
W_6	100	98	96	98	101	99	97	99	100	98	96	**98**	108	105	103	105	109	106	104	106	108	106	104	**106**
W_7	98	99	96	98	99	100	97	98	99	99	96	**98**	106	106	103	105	107	107	104	106	107	107	104	**106**
W_8	100	98	95	98	100	99	96	98	100	98	96	**98**	107	105	102	105	108	106	103	106	108	106	103	**105**
Mean	98	98	96	-	99	99	96	-	**99**	**99**	**96**	**-**	106	105	103	-	107	106	104	-	**107**	**106**	**103**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.1		0.4		0.1		0.6		0.1		**0.4**		0.4		1.7		0.4		1.4		0.4		**1.6**	
W	0.4		NS		0.4		NS		0.4		**NS**		0.4		NS		0.4		NS		0.4		**NS**	
W at F	0.6		1.7		0.7		NS		0.9		**NS**		0.6		1.8		0.7		NS		0.6		**NS**	
F X W	0.9		1.6		0.7		NS		0.8		**NS**		0.7		2.1		0.7		NS		0.7		**NS**	

110 % RDF (98 and 105 DAS, Table 4.22.) Among the wild oat management treatments, no herbicide showed significant variation in relation to 50 per cent spike and flowering. The interaction effect of fertilizer levels and herbicide treatments was found non-significant in relation to 50 per cent spike and flowering.

4.3.5 Panicle length (cm)

The pooled data of panicle length indicate that application of 100 % RDF recorded significantly lesser panicle length (25.2 cm) compared to 120 % RDF (26.9 cm), but RDF was at par with 110 % RDF (25.5 cm) with respect to panicle length (Table. 4.23).

Significantly higher panicle length was recorded in weedy check (27.5 cm) followed by pendimethalin @ 1.5 kg ha^{-1} (26.99 cm) and metribuzin @ 175 g ha^{-1} (26.7 cm). Pendimethalin + metribuzin (1.5 kg ha^{-1}) recorded significantly higher panicle length (26.1 cm) when compared with sulfosulfuron @ 25 g ha^{-1} (25.5 cm), whereas, clodinafop @ 60 g ha^{-1} recorded significantly lower panicle length (24.5 cm) when compared with sulfosulfuron @ 25 g ha^{-1}, but was significantly higher than the pinoxaden @ 50 g ha^{-1}. Application of pinoxaden @ 50 g ha^{-1} (23.7 cm) recorded significantly lesser panicle length compared rest of the treatments. The interaction of wild oat management treatments and fertilizer levels was found to non-significant for the panicle length.

4.3.6 Seeds per panicle

Pooled data indicates that application of 100 % RDF recorded significantly lower seeds/panicle (59.3) compared to 120 % RDF (61.8), but RDF was at par with 110% RDF (59.7).

Application of pinoxaden @ 50 g ha^{-1} resulted in significantly lower number (57.6) of seeds/panicle compared rest of the treatments. Significantly higher number of seeds/panicle was recorded in weedy check (62.7) followed by pendimethalin @ 1.5 kg ha^{-1} (61.4) and metribuzin @ 175 g ha^{-1} (61.2). Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly higher lower number of seeds panicle^{-1} (60.4) when compared with clodinafop @ 60 g ha^{-1} (59.3). Clodinafop @ 60 g ha^{-1} led to significantly lesser seeds/panicle when compared with sulfosulfuron @ 25 g ha^{-1} (60.3).

4.3.7 Test weight (g)

Application of 120 % RDF recorded significantly higher test weight (24.8 g). Significantly lower test weight was documented in RDF (23.6 g) which was at par with application of 110 % RDF *i.e.,* 23.7 g (Table. 4.23).

Table 4.23: Panicle length, seeds/panicle and test weight of wild oat as influenced by fertilizer levels and wild oat management treatments in wheat

W M T	Panicle length (cm)				Number of Seeds panicle^{-1}												Test weight (g)											
	Pooled				**2015-16**				**2016-17**				**Pooled**				**2015-16**				**2016-17**				**Pooled**			
	Fertilizer levels (F)				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**M_2**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	24.0	24.2	25.5	**24.6**	57.5	57.7	60.0	58.4	59.3	59.7	61.7	60.2	58.4	58.7	60.9	**59.3**	22.6	22.9	23.9	23.1	23.1	23.4	24.1	23.5	22.8	23.1	24.0	**23.3**
W_2	24.9	25.1	26.4	**25.5**	58.4	58.7	61.3	59.5	60.4	60.7	62.4	61.2	59.4	59.7	61.9	**60.3**	23.1	23.5	24.3	23.6	23.7	23.8	24.7	24.1	23.4	23.6	24.5	**23.8**
W_3	23.3	23.7	24.1	**23.7**	54.3	55.6	58.0	56.0	58.5	58.6	60.7	59.3	56.4	57.1	59.4	**57.6**	21.4	21.4	22.3	21.7	21.7	21.8	22.8	22.1	21.6	21.6	22.6	**21.9**
W_4	26.2	26.4	27.5	**26.7**	59.2	60.1	61.7	60.3	61.4	61.5	63.5	62.1	60.3	60.8	62.6	**61.2**	24.1	24.2	25.2	24.5	24.6	24.7	25.6	25.0	24.3	24.5	25.4	**24.7**
W_5	26.4	26.5	28.0	**27.0**	59.6	59.9	61.8	60.4	61.7	61.9	63.8	62.5	60.7	60.9	62.8	**61.5**	24.2	24.3	25.4	24.6	24.7	24.8	25.7	25.0	24.4	24.5	25.5	**56.7**
W_6	25.4	25.6	27.4	**26.2**	58.5	58.6	60.9	59.3	60.8	60.9	63.0	61.6	59.7	59.8	61.9	**60.5**	23.7	23.9	24.8	24.1	24.3	24.4	25.2	24.6	24.0	24.1	25.0	**24.4**
W_7	24.8	25.8	27.5	**26.0**	54.8	55.7	58.5	56.3	61.5	61.6	63.1	62.1	58.2	58.6	60.8	**59.2**	22.8	23.0	25.1	23.6	24.4	23.9	25.4	24.5	23.6	23.4	25.2	**24.1**
W_8	26.7	26.9	28.8	**27.5**	60.9	61.0	64.0	62.0	62.7	62.9	64.7	63.4	61.8	61.9	64.4	**62.7**	24.9	25.0	26.0	25.3	25.1	25.1	26.5	25.6	25.0	25.1	26.3	**25.4**
Mean	**25.2**	**25.5**	**26.9**	-	57.9	58.4	60.8	-	60.8	61.0	62.9	-	**59.3**	**59.7**	**61.8**	-	23.3	23.5	24.6	-	24.0	24.0	25.0	-	**23.6**	**23.7**	**24.8**	-
	SEm±		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**	
F	0.10		**0.38**		0.18		0.71		0.06		0.24		0.10		**0.40**		0.08		0.30		0.08		0.31		0.07		**0.26**	
W	0.27		**0.78**		0.39		1.10		0.19		0.55		0.19		**0.53**		0.08		0.23		0.10		0.29		0.06		**0.16**	
W at F	0.47		**NS**		0.67		NS		0.33		NS		0.32		**NS**		0.14		0.40		0.18		NS		0.10		**NS**	
F X W	0.45		**NS**		0.65		NS		0.32		NS		0.32		**NS**		0.15		0.43		0.18		NS		0.11		**NS**	

Among wild oat management treatments significantly lowest test weight was recorded with application of pinoxaden @ 50 g ha^{-1} (21.91 g) followed by clodinafop @ 60 g ha^{-1} *i.e.* 23.3 g which was significantly lower than the sulfosulfuron @ 25 g ha^{-1} (23.8 g) but higher than the pinoxaden @ 50 g ha^{-1}. Sulfosulfuron @ 25 g ha^{-1} recorded significantly lower test weight (23.8 g) when compared with the application of pendimethalin + metribuzin @ 1.5 kg ha^{-1} (24.3 g), whereas, significantly higher test weight was recorded in weedy check (25.4 g) followed by pendimethalin @ 1.5 kg ha^{-1} (24.8 g) and metribuzin @ 175 g ha^{-1} (24.7 g).

4.3.8 Field visual weed control observation

At 45 and 90 DAS (Table. 4.24 and Fig. 8), significantly higher visual weed control (63 and 60 %) was obtained with the application of RDF which was at par with the application of 110 % RDF (59.2 and 56.7 %). Significantly lower visual weed control was observed with the application of 120 % RDF (52.1and 47.1 %).

Application of pinoxaden @ 50 g ha^{-1} (80.62 and 78.21 %) recorded significantly higher visual weed control compared to all other treatments. Significantly lower visual weed control was resulted in pendimethalin @ 1.5 kg ha^{-1} (33.32 and 30.98 %) followed by metribuzin @ 175 g ha^{-1} (37.82 and 35.85 %). Clodinafop @ 60 g ha^{-1} recorded significantly higher visual weed control (69.43 and 65.20 %) when compared with sulfosulfuron @ 25 g ha^{-1} (52.18 and 49.15 %) but was significantly lower than the pinoxaden @ 50 g ha^{-1}.

The interaction effect of fertilizer levels and weed management treatments was significant with respect to visual weed control of wheat. Application of RDF with pinoxaden @ 50 g ha^{-1} resulted in significantly higher visual weed control of wheat (85.66 and 80.95 %) compared to all other treatment combinations, except F_2W_3, F_3W_3 with which it was at par. Significantly lower visual weed control was recorded with the combination of 120 % RDF with pendimethalin (30.45 and 24.79 %) compared to all other treatments followed by 110 % RDF with weedy check (32.50 and 33.07 %).

4.4 Analysis of nutrients

The data on nutrient uptake (N, P and K) content and as influenced by fertilizer levels and wild oat management treatments in wheat are presented in Tables 4.25 to 4.34.

4.4.1 Per cent content of nutrients

N, P and K content of wheat did not differ significantly due to fertilizer levels and wild oat management treatments (Tables 4.25 and 4.26).

Table 4.24: Effect of fertilizer levels and wild oat management treatments on visual weed control (%) in wheat field at 45 and 90 DAS

WMT	45 DAS												90 DAS											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	92.0	90.3	80.0	87.4	90.0	88.3	81.7	86.7	91.0	89.3	80.8	**87.1**	90.0	81.7	73.3	81.7	85.0	83.3	78.3	82.2	87.5	82.5	75.8	**81.9**
W_2	71.3	68.7	53.3	64.4	68.3	61.7	50.0	60.0	69.8	65.2	51.7	**62.2**	70.0	61.7	45.0	58.9	65.0	60.0	41.0	55.3	67.5	60.8	43.0	**57.1**
W_3	100	95.3	96.7	97.3	96.7	95.0	95.0	95.6	98.3	95.2	95.8	**96.4**	96.0	95.0	94.3	95.1	96.7	95.0	95.0	95.6	96.3	95.0	94.7	**95.3**
W_4	45.3	42.2	31.0	39.5	43.3	35.0	30.0	36.1	44.3	38.6	30.5	**37.8**	43.3	41.7	25.0	36.7	43.3	31.7	23.3	32.8	43.3	36.7	24.2	**34.7**
W_5	37.7	33.2	28.3	33.1	35.0	25.0	23.3	27.8	36.3	29.1	25.8	**30.4**	36.7	35.0	18.7	30.1	30.0	25.0	16.7	23.9	33.3	30.0	17.7	**27.5**
W_6	66.3	62.3	39.7	56.1	63.3	55.0	33.0	50.4	64.8	58.7	36.3	**53.3**	60.0	55.0	28.3	47.8	61.7	53.3	28.3	47.8	60.8	54.2	28.3	**47.8**
W_7	99.7	98.0	96.3	98.0	98.3	96.7	95.0	96.7	99.0	97.3	95.7	**97.3**	98.3	93.3	93.3	95.0	98.3	95.0	93.3	95.6	98.3	94.2	93.3	**95.3**
W_8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Mean	64.0	61.3	53.2	-	61.9	57.1	51.0	-	**63.0**	**59.2**	**52.1**	**-**	61.8	57.9	47.3	-	60.0	55.4	47.0	-	**60.9**	**56.7**	**47.1**	**-**
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.89		3.48		0.61		2.38		0.63		**2.46**		1.00		3.93		0.90		3.55		0.73		**2.87**	
W	1.71		4.88		1.39		3.96		1.14		**3.24**		1.41		4.02		1.48		4.23		1.18		**3.36**	
W at F	2.96		8.46		2.40		6.86		1.97		**5.61**		2.44		6.96		2.57		7.33		2.04		**5.82**	
F X W	2.91		8.31		2.33		6.64		1.94		**5.55**		2.49		7.11		2.57		7.33		2.04		**5.83**	

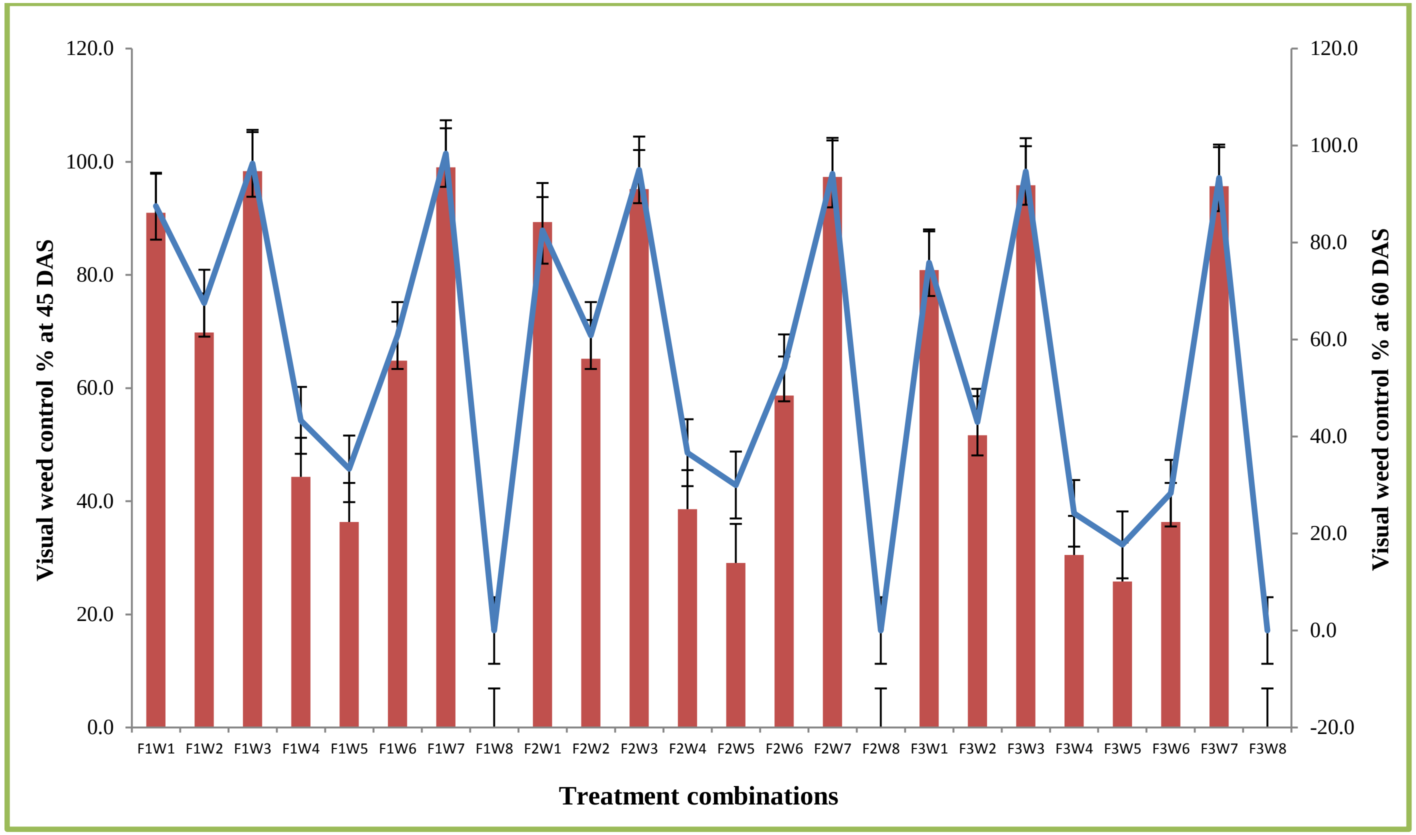


Fig 8: Effect of fertilizer levels and wild oat management treatments on visual weed control (%) at 45 and 60 DAS in wheat field.

Table 4.25: Per cent content of N, P and K in wheat grain as influenced by fertilizer levels and wild oat management treatments

F.L (F)	Nitrogen (%)			Phosphorous (%)			Potassium (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
F_1	1.46	1.46	1.46	0.30	0.30	0.30	0.72	0.76	0.74
F_2	1.45	1.45	1.45	0.29	0.30	0.30	0.72	0.76	0.74
F_3	1.44	1.44	1.44	0.29	0.29	0.29	0.69	0.75	0.72
SEm±	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Wild oat management treatments (W)									
W_1	1.49	1.50	1.49	0.29	0.29	0.29	0.72	0.78	0.75
W_2	1.40	1.40	1.40	0.29	0.28	0.28	0.71	0.75	0.73
W_3	1.58	1.57	1.57	0.32	0.34	0.33	0.83	0.87	0.85
W_4	1.39	1.39	1.39	0.28	0.28	0.28	0.64	0.72	0.68
W_5	1.38	1.38	1.38	0.28	0.28	0.28	0.63	0.70	0.67
W_6	1.40	1.40	1.40	0.28	0.28	0.28	0.70	0.75	0.73
W_7	1.59	1.58	1.58	0.32	0.34	0.33	0.84	0.88	0.86
W_8	1.40	1.37	1.38	0.28	0.28	0.28	0.61	0.61	0.61
SEm±	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4.26: Per cent content of N, P and K in wheat straw as influenced by fertilizer levels and wild oat management treatments

F.L (F)	Nitrogen (%)			Phosphorous (%)			Potassium (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
F_1	0.55	0.55	0.55	0.08	0.08	0.08	1.79	1.78	1.78
F_2	0.55	0.55	0.55	0.08	0.08	0.08	1.78	1.78	1.78
F_3	0.54	0.54	0.54	0.07	0.07	0.07	1.76	1.76	1.76
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Wild oat management treatments (W)									
W_1	0.58	0.56	0.57	0.08	0.08	0.08	1.82	1.77	1.79
W_2	0.54	0.53	0.53	0.08	0.08	0.08	1.73	1.71	1.72
W_3	0.60	0.61	0.60	0.09	0.09	0.09	1.93	2.12	2.02
W_4	0.52	0.51	0.52	0.07	0.07	0.07	1.67	1.60	1.63
W_5	0.52	0.51	0.52	0.07	0.07	0.07	1.68	1.60	1.64
W_6	0.55	0.52	0.54	0.07	0.07	0.07	1.79	1.64	1.72
W_7	0.60	0.61	0.60	0.09	0.09	0.09	1.96	2.13	2.05
W_8	0.49	0.50	0.50	0.06	0.06	0.06	1.62	1.63	1.63
SEm±	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.4.2 Nitrogen uptake by wheat

Nitrogen uptake by wheat grain, straw and total uptake of nitrogen by wheat was recorded after harvest of the crop and documented in (Table 4.27 and 4.28) in both the years.

4.4.2.1 Nitrogen uptake by wheat grain

Among the fertilizer levels, significantly higher mean nitrogen uptake by wheat grain (65.3 kg ha^{-1}) was obtained with the application of RDF which was at par with the application of 110 % RDF (63.8 kg ha^{-1}). Significantly lower nitrogen uptake by wheat grain was recorded with the application of 120 % RDF (58.7 kg ha^{-1}) as compared to rest of fertilizer levels (Table. 4.27).

Weed free (87.6 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (86.3 kg ha^{-1}) recorded significantly higher nitrogen uptake by wheat grain compared to rest of the treatments, but were statistically at par with each other. Significantly lower nitrogen uptake by wheat grain was documented in weedy check (43.3 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (48.7 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (50.1 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher nitrogen uptake by wheat grain (69.9 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (60.2 kg ha^{-1}) pendimethalin, metribuzine and pendimethalin + metribuzine but was significantly lower than the pinoxaden @ 50 g ha^{-1} and weed free condition.

The interaction effect of fertilizer levels and weed management treatments was significant with respect to nitrogen uptake by grain of wheat. Application of 120 % RDF + weed free situation resulted in significantly higher nitrogen uptake by wheat grain (88.9 kg ha^{-1}) compared to rest of treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3 with which were at par with each other. Significantly lower nitrogen uptake by wheat grain was recorded with the combination of 120 % RDF + weedy check (37.8 kg ha^{-1}) compared to rest of treatment combinations followed by weedy + 110 % RDF (44.5 kg ha^{-1}) and weedy + RDF (47.5 kg ha^{-1}) show at par relation with each other but significantly higher than the 120 % RDF with weedy check.

4.4.2.2 Nitrogen uptake by wheat straw

Significantly lower nitrogen uptake in wheat straw was recorded with the application of 120 % RDF (33.7 kg ha^{-1}) whereas significantly higher nitrogen uptake in wheat straw was recorded with RDF (37.5 kg ha^{-1}) which was at par with the application of 110 % RDF (36.8 kg ha^{-1}) (Table. 4.27).

Table 4.27: Nitrogen uptake (kg ha^{-1}) by wheat grain and straw as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Grain uptake (kg ha^{-1})												Straw uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	71.4	67.0	58.6	65.7	79.1	77.1	66.7	74.3	75.2	72.1	62.6	**70.0**	40.2	39.4	33.1	37.5	43.9	43.3	38.8	42.0	42.1	41.3	35.9	**39.8**
W_2	60.1	57.8	48.2	55.4	69.4	67.4	58.7	65.2	64.7	62.6	53.5	**60.3**	36.0	35.2	28.0	33.0	40.2	38.4	33.8	37.5	38.1	36.8	30.9	**35.3**
W_3	82.1	82.1	85.2	83.1	87.9	89.1	91.2	89.4	85.0	85.6	88.2	**86.3**	43.7	44.9	46.8	45.1	48.6	49.0	52.1	49.9	46.1	46.9	49.5	**47.5**
W_4	49.9	47.1	41.5	46.2	59.0	54.5	48.7	54.1	54.4	50.8	45.1	**50.1**	29.1	29.1	24.0	27.4	33.6	32.1	28.1	31.3	31.3	30.6	26.1	**29.3**
W_5	49.1	45.9	40.2	45.1	56.1	53.4	47.3	52.3	52.6	49.7	43.7	**48.7**	29.6	27.8	23.7	27.0	33.4	31.9	27.6	31.0	31.5	29.8	25.6	**29.1**
W_6	54.9	53.1	45.3	51.1	65.7	63.3	54.2	61.0	60.3	58.2	49.7	**56.1**	33.9	32.1	27.7	31.2	37.3	35.9	30.3	34.5	35.6	34.0	29.0	**32.9**
W_7	83.8	84.0	86.0	84.6	90.2	89.5	91.9	90.5	87.0	86.8	89.0	**87.6**	44.2	45.6	47.2	45.7	48.0	49.8	52.3	50.0	46.1	47.7	49.7	**47.8**
W_8	45.7	41.6	36.0	41.1	49.3	47.3	39.6	45.4	47.5	44.5	37.8	**43.3**	26.6	25.0	20.6	24.0	31.5	29.7	25.2	28.8	29.0	27.3	22.9	**26.4**
Mean	62.1	59.8	55.1	-	69.6	67.7	62.3	-	**65.3**	**63.8**	**58.7**	-	35.4	34.9	31.4	-	39.6	38.8	36.0	-	**37.5**	**36.8**	**33.7**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.7		2.7		0.9		3.7		0.4		**2.1**		0.4		1.4		0.6		2.4		0.4		**1.7**	
W	1.4		4.0		1.5		4.3		1.3		**3.6**		1.1		3.1		1.0		2.9		0.9		**2.7**	
W at F	2.5		NS		2.6		NS		2.2		**6.2**		1.9		NS		1.7		NS		1.6		**4.7**	
F X W	2.4		NS		2.6		NS		2.1		**5.9**		1.8		NS		1.7		NS		1.6		**4.5**	

Significantly lower nitrogen uptake in wheat straw was observed in weedy check (26.4 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (28.9 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (29.3 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher nitrogen uptake in wheat straw (39.7 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (35.2 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1} and weed free condistion. Weed free (47.8 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (47.5 kg ha^{-1}) recorded significantly higher nitrogen uptake by wheat straw compared to rest of the treatments, but were statistically at par with each other (Table. 4.27)

The interaction effect of fertilizer levels and wild oat management treatments differ significantly with respect to nitrogen uptake by wheat straw. Significantly lower nitrogen uptake by wheat straw was recorded with 120 % RDF + weedy check (22.9 kg ha^{-1}) compared to rest of the treatment combinations. Application of 110 % RDF to weedy check (27.3 kg ha^{-1}) and weedy check + RDF (29.1 kg ha^{-1}). Application of 120 % RDF +weed free situation resulted in significantly higher nitrogen uptake by wheat straw (49.7 kg ha^{-1}).

4.4.2.3 Nitrogen uptake (grain +straw) in wheat

Among the fertilizer levels, significantly higher nitrogen uptake by wheat crop (103.3 kg ha^{-1}) was obtained with the application of RDF which was at par with the application of 110 % RDF (100.6 kg ha^{-1}). Significantly lower mean total nitrogen uptake by wheat crop was observed with the application of 120 % RDF (Table. 4.28).

Weed free (135.4 kg ha^{-1}) and pinoxaden @ 50 g ha^{-1} (133.8 kg ha^{-1}) being at par with each other accumulated significantly higher nitrogen compared to rest of the wild oat management treatments during both the years as well as in pooled data. Significantly lower nitrogen uptake by wheat crop was recorded in weedy check (69.6 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (77.7 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (79.5kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher nitrogen uptake by wheat crop (109.7 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (95.5 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1}.

The interaction of fertilizer levels and weed management treatments was significant with respect to mean total nitrogen uptake by wheat crop (Table. 4.28). Application of 120 % RDF + weed free resulted in significantly higher nitrogen uptake by wheat crop (138.7 kg ha^{-1}) compared to rest of the treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3. Significantly lower nitrogen uptake by wheat crop was recorded with the combination of 120% RDF + weedy check (60.7 kg ha^{-1}) compared to rest of the treatments followed by 110 % RDF + weedy check (71.8 kg ha^{-1}) and weedy check in RDF (76.5 kg ha^{-1}) show at par relation with each other but resulted significantly higher nitrogen uptake than the 120 % RDF with weedy check. Nitrogen uptake by wheat crop in weed free and pinoxaden @ 50 g ha^{-1} was statistically similar at all the fertilizer levels.

Table 4.28: Nitrogen uptake (kg ha^{-1}) by wheat (grain + straw) as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Nitrogen uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	111.6	106.4	91.7	103.2	123.0	120.4	105.5	116.3	117.3	113.4	98.6	**109.8**
W_2	96.1	92.9	76.2	88.4	109.6	105.8	92.5	102.6	102.8	99.3	84.4	**95.5**
W_3	125.8	127.0	132.0	128.3	136.4	138.1	143.3	139.3	131.1	132.6	137.7	**133.8**
W_4	78.9	76.2	65.5	73.5	92.6	86.7	76.8	85.3	85.7	81.4	71.1	**79.4**
W_5	78.7	73.7	63.9	72.1	89.5	85.3	74.8	83.2	84.1	79.5	69.4	**77.7**
W_6	88.8	85.3	72.9	82.3	103.0	99.2	84.5	95.5	95.9	92.2	78.7	**88.9**
W_7	128.0	129.7	133.2	130.3	138.2	139.3	144.2	140.5	133.1	134.5	138.7	**135.4**
W_8	72.2	66.6	56.6	65.2	80.8	77.0	64.8	74.2	76.5	71.8	60.7	**69.7**
Mean	97.5	94.7	86.5	-	109.1	106.5	98.3	-	**103.3**	**100.6**	**92.4**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.8		3.0		1.1		4.2		0.8		**2.8**	
W	2.0		5.7		1.9		5.4		1.7		**4.9**	
W at F	3.5		9.9		3.3		9.4		3.0		**8.5**	
F X W	3.3		9.5		3.3		9.3		2.8		**8.0**	

4.4.3 Phosphorus uptake in wheat

Phosphors uptake by wheat grain, straw and total uptake of phosphorus by wheat was recorded at harvest of the crop and documented in Table 4.29 and 4.30.

4.4.3.1 Phosphorus uptake in wheat grain

Pooled data indicated significantly lower mean phosphorus uptake in wheat grain with the application of 120 % RDF (11.7 kg ha^{-1}) as compared to RDF (13.4 kg ha^{-1}) and 110 % RDF (13.1 kg ha^{-1}).

Significantly lower mean phosphorus uptake in wheat grain was obtained in weedy check (8.7 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (9.9 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (10.1 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher phosphorus uptake in wheat grain (13.5 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (12.2 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1}. Weed free (18.2 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (17.9 kg ha^{-1}) recorded significantly higher phosphorus uptake by wheat grain compared to rest of the treatments, but were statistically at par with each other. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly higher uptake of phosphorus when compared with alone pendimethalin @ 1.5 kg ah^{-1} or metribuzin @ 175 g ha^{-1} interaction between fertilizer levels and weed management practices for phosphours uptake by grain was non significant (Table. 4.29).

4.4.3.2 Phosphorus uptake in wheat straw

The highest mean phosphorus uptake in wheat straw (5.3 kg ha^{-1}) was obtained with the application of RDF which was at par with the application of 110 % RDF (5.2 kg ha^{-1}) but significantly higher than application of 120 % RDF (Table. 4.29).

During both the years as well as in pooled data weed free (7.1 kg ha^{-1}) and pinoxaden @ 50 g ha^{-1} (6.9 kg ha^{-1}) being at par with each other accumulated significantly higher phosphorus in wheat straw compared to rest of the wild oat management treatments Significantly lower phosphorus uptake in wheat straw was documented in weedy check (3.4 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (3.8 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (3.9 kg ha^{-1}) resulted in statstically similar but significantly higher mean phosphorus uptake in straw than weedy check. Clodinafop @ 60 g ha^{-1} recorded significantly higher phosphorus uptake by wheat straw (5.6 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (5.1 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50g ha^{-1} and weed free condition.

Table 4.29: Phosphorus uptake (kg ha^{-1}) by wheat grain and straw as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	**Grain uptake (kg ha^{-1})**												**Straw uptake (kg ha^{-1})**											
	2015-16				**2016-17**				**Pooled**				**2015-16**				**2016-17**				**Pooled**			
	Fertilizer levels (F)				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**				**Fertilizer levels (F)**			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	13.8	13.0	11.4	12.7	15.3	15.0	12.5	14.3	14.6	14.0	11.9	**13.5**	5.7	5.5	4.2	5.2	6.3	6.3	5.5	6.0	6.0	5.9	4.9	**5.6**
W_2	12.2	11.8	9.9	11.3	14.1	13.7	11.7	13.2	13.1	12.7	10.8	**12.2**	5.1	5.0	3.8	4.6	5.9	5.8	4.7	5.5	5.5	5.4	4.3	**5.1**
W_3	16.9	17.0	16.3	16.7	18.8	19.0	19.7	19.1	17.8	18.0	18.0	**17.9**	6.3	6.6	7.2	6.7	6.8	7.1	7.8	7.3	6.5	6.9	7.5	**7.0**
W_4	10.0	9.6	8.4	9.3	12.0	11.1	9.3	10.8	11.0	10.4	8.8	**10.1**	4.0	3.9	3.0	3.6	4.8	4.5	3.6	4.3	4.4	4.2	3.3	**4.0**
W_5	9.9	9.3	8.3	9.2	11.4	10.9	9.3	10.6	10.7	10.1	8.8	**9.9**	4.1	3.8	2.9	3.6	4.7	4.4	3.4	4.2	4.4	4.1	3.1	**3.9**
W_6	11.1	10.8	9.3	10.4	13.3	12.7	10.5	12.2	12.2	11.8	9.9	**11.3**	4.6	4.4	3.5	4.1	5.2	5.0	4.3	4.8	4.9	4.7	3.9	**4.5**
W_7	17.0	17.2	16.6	16.9	19.1	19.2	19.9	19.4	18.1	18.2	18.2	**18.2**	6.4	6.7	7.2	6.8	7.0	7.2	8.0	7.4	6.7	7.0	7.6	**7.1**
W_8	9.2	8.4	7.2	8.3	10.0	9.7	8.0	9.3	9.6	9.0	7.6	**8.8**	3.6	3.5	2.4	3.2	4.3	4.0	2.9	3.7	3.9	3.7	2.7	**3.4**
Mean	12.5	12.1	10.9	-	14.3	13.9	12.6	-	**13.4**	**13.0**	**11.8**	-	5.0	4.9	4.3	-	5.6	5.5	5.0	-	**5.3**	**5.2**	**4.6**	**-**
	SEm±		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**		**SEm±**		**CD at 5%**	
F	0.2		0.9		0.2		0.6		0.1		**0.5**		0.0		0.1		0.1		0.2		0.0		**0.1**	
W	0.4		1.1		0.4		1.2		0.3		**0.9**		0.1		0.4		0.1		0.3		0.1		**0.2**	
W at F	0.7		NS		0.7		NS		0.6		**NS**		0.2		0.7		0.2		0.4		0.5		**NS**	
F X W	0.7		NS		0.7		NS		0.5		**NS**		0.2		0.6		0.2		0.4		0.6		**NS**	

4.4.3.3 Phosphorus uptake (grain + straw) in wheat

Table 4.30 revealed that significantly higher phosphorus uptake by wheat (18.7 kg ha^{-1}) was obtained with the application of RDF as compared with 120 % RDF (16.4 kg ha^{-1}). However, RDF was at par with the application of 110 % RDF (18.3 kg ha^{-1}).

Clodinafop @ 60 g ha^{-1} recorded significantly higher phosphorus uptake by wheat crop (19.1 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (17.3 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1} and weed free condition. Significantly lower phosphorus uptake by wheat crop was documented in weedy check (12.2 kg ha^{-1}) over all other treatments, pendimethalin @ 1.5 kg ha^{-1} (13.7 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (14.1 kg ha^{-1}) recorded statistically similar but significantly higher total phosphorus uptake than weedy check. Weed free (25.2 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (24.9 kg ha^{-1}) recorded significantly higher phosphorus uptake by wheat crop compared rest of the other treatments, but were statistically at par with each other (Table. 4.30).

The interaction effect of fertilizer levels and weed management treatments was significant with respect to phosphorus uptake by wheat crop. Application of 120 % RDF with weed free situation resulted in significantly higher phosphorus uptake by wheat crop (25.83 kg ha^{-1}) compared to rest of the treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3. Significantly lower phosphorus uptake by wheat crop was recorded with the combination of 120 % RDF + weedy check (10.2 kg ha^{-1}) compared rest of the treatments followed by 110 % RDF + weedy check (12.7 kg ha^{-1}) and RDF in weedy check (13.5 kg ha^{-1}) were show at par with each other but significantly higher phosphorus uptake than the 120 % RDF with weedy check. Phosphorus uptake by wheat crop in weed free situation and pinoxaden @ 50 g ha^{-1} was statistically similar at all the fertilizer levels.

4.4.4 Potassium uptake by wheat

Potassium uptake by wheat grain and straw as well as total up take of phosphorus by wheat recorded after harvest of the crop and documented in Table 4.31 and 4.32.

4.4.4.1 Potassium uptake in wheat grain

Significantly higher mean potassium uptake in wheat grain (33.6 kg ha^{-1}) was obtained with the application of RDF which was on par with the application of 110 % RDF (32.8 kg ha^{-1}). Significantly lower potassium uptake in wheat grain was observed with the application of 120 % RDF (30.2 kg ha^{-1}) (Table. 4.31).

Weed free (47.6 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (46.8 kg ha^{-1}) recorded significantly higher potassium uptake in wheat grains compared to rest of the treatments, but were statistically at par with each other.

Table 4.30: Phosphorus uptake (kg ha^{-1}) by wheat (grain + straw) as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Phosphorus uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	19.5	18.6	15.6	17.9	21.7	21.3	18.0	20.3	20.6	19.9	16.8	**19.1**
W_2	17.3	16.8	13.7	15.9	20.0	19.5	16.5	18.7	18.7	18.1	15.1	**17.3**
W_3	23.1	23.6	23.4	23.4	25.6	26.1	27.5	26.4	24.4	24.8	25.5	**24.9**
W_4	14.0	13.6	11.3	13.0	16.9	15.6	12.9	15.1	15.5	14.6	12.1	**14.0**
W_5	14.0	13.2	11.2	12.8	16.2	15.3	12.7	14.7	15.1	14.3	11.9	**13.8**
W_6	15.7	15.2	12.7	14.5	18.5	17.8	14.8	17.0	17.1	16.5	13.8	**15.8**
W_7	23.4	23.9	23.8	23.7	26.1	26.4	27.8	26.8	24.7	25.2	25.8	**25.2**
W_8	12.8	11.8	9.6	11.4	14.3	13.7	10.9	13.0	13.6	12.8	10.3	**12.2**
Mean	17.5	17.1	15.2	-	19.9	19.5	17.6	-	**18.7**	**18.3**	**16.4**	-

	SEm± (2015-16)	CD at 5% (2015-16)	SEm± (2016-17)	CD at 5% (2016-17)	SEm± (Pooled)	CD at 5% (Pooled)
F	0.2	1.0	0.2	0.8	0.2	**0.6**
W	0.4	1.2	0.4	1.1	0.3	**1.0**
W at F	0.7	NS	0.7	2.0	0.6	**1.7**
F X W	0.7	NS	0.7	1.9	0.6	**1.6**

Significantly lower potassium uptake by wheat grain was documented in weedy check (19.1 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (23.6 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (24.5 kg ha^{-1}) resulted in stasticaly similar but significantly higher mean potassium uptake than weedy check. Clodinafop @ 60 g ha^{-1} recorded significantly higher potassium uptake in wheat grains (32.3 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (31.6 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1} and weed free condition. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly higher uptake of phosphorus compared with alone application of pendimethalin @ 1.5 g ha^{-1} or metribuzin @ 175 g ha^{-1}.

Application of 120 % RDF with weed free situation resulted in significantly higher mean combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3 and these were at par with each other. Significantly lower potassium uptake in wheat grain was recorded with the combination of 120 % RDF + weedy check (16.7 kg ha^{-1}) compared to rest of the treatments followed by 110 % RDF + weedy check (19.7 kg ha^{-1}) and weedy check in RDF (20.7 kg ha^{-1}).

4.4.4.2 Potassium uptake in wheat straw

Significantly lower mean potassium uptake by wheat straw was observed with the application of 120 % RDF (109.8 kg ha^{-1}) ,whereas, significantly higher potassium uptake by wheat straw was obtained with RDF (121.7 kg ha^{-1}) which was at par with the application of 110 % RDF (119.6 kg ha^{-1}) (Table. 4.31).

Based on pooled data it was observed that significantly lower potassium uptake by wheat straw was recorded in weedy check (85.88 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (92.1 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (93.1 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher mean potassium uptake by wheat straw (125.1 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (113.7 kg ha^{-1}) but was significantly lower than the pinoxaden and weed free condition. Weed free (162.1 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (159.3 kg ha^{-1}) recorded significantly higher potassium uptake by wheat straw compared to rest of the treatments, but were statistically at par with each other.

The interaction effect of fertilizer levels and wild oat management treatments was significant with respect to mean potassium uptake by wheat straw (Table. 4.31). The lowest potassium uptake by wheat straw was recorded with the combination of 120 % RDF with weedy check (76.8 kg ha^{-1}) compared to rest of the treatment combinations, followed by 110 % RDF with weedy check (88.4 kg ha^{-1}) but significantly lower than all other treatments. Application of 120 % RDF with weed free situation resulted in significantly higher potassium uptake by wheat straw (167.4 kg ha^{-1}) than all treatment combinations except F_2W_7, F_1W_7, F_2W_3 and F_1W_3 .

Table 4.31: Potassium uptake (kg ha^{-1}) by wheat grain and straw as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Grain uptake (kg ha^{-1})												Straw uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	36.4	34.2	25.0	31.9	42.2	39.6	34.3	38.7	39.3	36.9	29.7	**35.3**	129.1	124.1	101.4	118.2	138.4	136.3	121.3	132.0	133.7	130.2	111.3	**125.1**
W_2	31.4	30.4	22.3	28.1	37.7	35.7	31.9	35.1	34.5	33.1	27.1	**31.6**	116.3	113.6	89.9	106.6	127.9	125.0	110.0	121.0	122.1	119.3	100.0	**113.8**
W_3	42.1	42.7	46.9	43.9	47.5	49.1	52.5	49.7	44.8	45.9	49.7	**46.8**	140.5	144.9	149.9	145.1	168.8	172.8	179.2	173.6	154.6	158.8	164.5	**159.3**
W_4	23.3	22.2	18.0	21.2	30.8	28.0	25.0	27.9	27.0	25.1	21.5	**24.5**	94.0	90.9	77.9	87.6	106.9	100.8	88.1	98.6	100.4	95.8	83.0	**93.1**
W_5	22.6	21.5	17.6	20.5	29.1	27.4	23.6	26.7	25.8	24.4	20.6	**23.6**	95.3	89.5	77.5	87.4	105.3	99.8	85.5	96.9	100.3	94.7	81.5	**92.2**
W_6	27.6	26.6	22.9	25.7	35.8	34.1	28.2	32.7	31.7	30.4	25.5	**28.9**	108.9	104.9	91.5	101.8	116.0	111.9	95.8	107.9	112.5	108.4	93.7	**104.9**
W_7	42.9	43.9	48.2	45.0	47.7	49.9	53.3	50.3	45.3	46.9	50.7	**47.7**	144.9	147.1	154.9	149.0	170.1	175.3	180.0	175.1	157.5	161.2	167.5	**162.0**
W_8	19.5	17.9	16.3	17.9	22.0	21.5	17.2	20.2	20.8	19.7	16.8	**19.1**	84.9	82.7	69.4	79.0	99.7	94.3	84.3	92.8	92.3	88.5	76.8	**85.9**
Mean	30.7	29.9	27.1	-	36.6	35.7	33.3	-	**33.7**	**32.8**	**30.2**	-	114.2	112.2	101.6	-	129.1	127.0	118.0	-	**121.7**	**119.6**	**109.8**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.8		NS		0.8		NS		0.5		**1.9**		1.6		6.4		1.9		7.3		1.5		**5.9**	
W	1.0		2.8		1.1		3.0		0.8		**2.4**		2.0		5.6		2.4		6.9		1.5		**6.9**	
W at F	1.7		4.8		1.8		5.2		1.5		**4.2**		3.4		9.7		4.2		11.9		4.8		**13.5**	
F X W	1.8		5.0		1.9		5.3		1.4		**4.1**		3.6		10.2		4.3		12.3		4.3		**12.3**	

4.4.4.3 Potassium uptake (grain + straw) in wheat

The highest mean potassium uptake by wheat crop (155.3 kg ha^{-1}) was obtained with the application of RDF which was at par with the application of 110 % RDF (152.2 kg ha^{-1}). Significantly lower potassium uptake by wheat crop was observed with the application of 120 % RDF (140.2 kg ha^{-1}) (Table. 4.35).

Significantly lower mean total potassium uptake by wheat crop was recorded in weedy check (104.9 kg ha^{-1}) than all other treatments, followed by pendimethalin @ 1.5 kg ha^{-1} (115.6 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (117.5 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher potassium uptake by wheat crop (160.7 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (145.5 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1}. Weed free (209.7 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (206.1 kg ha^{-1}) were statistically at par with each other and recorded significantly higher potassium uptake by wheat crop as compared rest of the other treatments.

The interaction effect of fertilizer levels and weed management treatments was significant with respect to potassium uptake by wheat crop (Table. 4.32). Application of 120 % RDF with weed free treatment resulted in significantly higher potassium uptake by wheat crop (218.2 kg ha^{-1}) compared to rest of the treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3. Significantly lower potassium uptake by wheat crop was recorded with the combination of 120 % RDF + weedy check (93.6 kg ha^{-1}) compared to rest of the treatments. Phosphorus uptake by wheat crop in weed free situation and pinoxaden @ 50 g ha^{-1} was statistically similar at all the fertilizer levels. Irrespective of fertilizer levels phosphorus uptake by wheat crop in pendimethalin and metribuzin was statistically at par but significantly higher values were noticed in RDF which was at par with 110 % RDF.

4.4.5 Nutrient uptake by wild oat

Nutrient uptake by wild oat i.e. nitrogen, phosphorus and potassium was recorded after harvest of the crop and documented in Table 4.33 and 4.34 in both the year.

4.4.5.1 Nitrogen uptake by wild oat

Significantly higher nitrogen uptake by wild oat was obtained with 120 % RDF (12.5 kg ha^{-1}), over RDF (7.5 kg ha^{-1}) which was at par with the application of 110 % RDF (8.2 kg ha^{-1}) (Table. 4.33).

Table 4.32: Potassium uptake (kg ha^{-1}) by wheat (grain + straw) as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Potassium uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	165.5	157.8	129.0	150.8	180.6	175.9	155.6	170.7	173.0	166.9	142.3	**160.7**
W_2	147.7	143.6	113.5	134.9	165.6	160.7	141.9	156.1	156.7	152.2	127.7	**145.5**
W_3	182.6	187.6	196.9	189.0	216.2	221.9	231.7	223.3	199.4	204.7	214.3	**206.1**
W_4	117.3	112.1	95.9	108.4	137.6	128.8	113.1	126.5	127.5	120.5	104.5	**117.5**
W_5	117.9	110.1	95.1	107.7	134.3	127.2	109.1	123.5	126.1	118.6	102.1	**115.6**
W_6	136.5	131.5	114.4	127.5	151.8	146.1	124.0	140.6	144.2	138.8	119.2	**134.1**
W_7	187.9	191.0	203.1	194.0	217.8	225.2	233.4	225.4	202.8	208.1	218.2	**209.7**
W_8	104.4	100.6	85.7	96.9	121.7	115.7	101.5	113.0	113.1	108.2	93.6	**105.0**
Mean	145.0	141.8	129.2	-	165.7	162.7	151.3	-	**155.3**	**152.2**	**140.2**	-

	2015-16 SEm±	2015-16 CD at 5%	2016-17 SEm±	2016-17 CD at 5%	Pooled SEm±	Pooled CD at 5%
F	1.6	6.4	1.5	5.8	1.4	**5.7**
W	2.7	7.6	2.5	7.2	1.9	**5.5**
W at F	4.6	13.2	4.4	12.4	3.3	**9.5**
F X W	4.6	13.2	4.3	12.4	3.4	**9.8**

Weed free (0.4 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (0.7 kg ha^{-1}) recorded significantly lower nitrogen uptake by wild oat compared to rest of the treatments, but were statistically at par with each other. Significantly higher nitrogen uptake by wild oat was documented in weedy check (24.6 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (16.2 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (13.9 kg ha^{-1}) recorded stastically similar but significantly higher nitrogen uptake than weedy check. Clodinafop @ 60 g ha^{-1} recorded significantly lower nitrogen uptake by wild oat (2.7 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (7.4 kg ha^{-1}) and but was significantly higher than the pinoxaden and weed free condition.

The interaction effect of fertilizer levels and weed management treatments was significant with respect to nitrogen uptake by wild oat. Application of RDF with weed free situation resulted in significantly lower nitrogen uptake by wild oat (0.5 kg ha^{-1}) which was on par with the F_1W_3, F_2W_3, F_3W_3, F_2W_7 and F_3W_7. Significantly higher nitrogen uptake by wild oat was recorded with 120 % RDF in weedy check (30.3 kg ha^{-1}) than all other treatments.

4.4.5.2 Phosphorus uptake by wild oat

Significantly higher mean phosphorus uptake by wild oat was obtained with 120 % RDF (3.8 kg ha^{-1}). Significantly lower phosphorus uptake by wild oat was observed with the application of RDF (2.3 kg ha^{-1}) which was on par with the application of 110 % RDF (2.5 kg ha^{-1}).

Weed free (0.1 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (0.2 kg ha^{-1}) recorded significantly lower phosphorus uptake by wild oat compared to rest of the treatments, but were statistically at par with each other (Table. 4.33). Significantly higher phosphorus uptake by wild oat was documented in weedy check (7.6 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (5.2 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (4.6 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly lower phosphorus uptake by wild oat (0.7 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (2.1 kg ha^{-1}) but was significantly higher than the pinoxaden @ 50 g ha^{-1}.

The interaction effect of fertilizer levels and weed management treatments was significant with respect to phosphorus uptake by wild oat. Application of RDF with weed free situation resulted in significantly lower phosphorus uptake by wild oat (0.1 kg ha^{-1}) which was at par with the F_1W_3, F_2W_3, F_3W_3, F_2W_7, and F_3W_7. Significantly higher phosphorus uptake by wild oat was recorded with 120 % RDF in weedy check (9.9 kg ha^{-1}) compared to rest of the treatments followed by 110 % RDF with weedy check (6.6 kg ha^{-1}). Phosphorus uptake by wheat crop in pendimethalin and metribuzin treated plots were statistically similar at all fertility level. However application of 120 % RDF resulted in significantly higher phosphours uptake than RDF and 110 % RDF in case of pendimethaline and metribuzine application and weedy check.

Table 4.33: Nitrogen and phosphorus uptake (kg ha^{-1}) by wild oat as influenced fertilizer levels and wild oat management treatments in wheat

WMT	Nitrogen uptake (kg ha^{-1})												Phosphorus uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	1.3	1.6	4.4	2.5	1.8	2.4	5.1	3.1	1.6	2.0	4.8	**2.8**	0.4	0.4	1.0	0.6	0.5	0.6	1.2	0.8	0.4	0.5	1.1	**0.7**
W_2	4.9	5.6	10.0	6.8	5.9	6.6	11.6	8.0	5.4	6.1	10.8	**7.4**	1.5	1.7	2.6	1.9	1.8	2.0	3.0	2.3	1.6	1.9	2.8	**2.1**
W_3	0.4	0.7	0.9	0.7	0.5	0.6	1.0	0.7	0.5	0.7	1.0	**0.7**	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.2	**0.2**
W_4	10.5	11.8	17.2	13.2	11.7	13.4	19.4	14.8	11.1	12.6	18.3	**14.0**	3.3	3.9	5.8	4.3	3.7	4.3	6.6	4.9	3.5	4.1	6.2	**4.6**
W_5	12.0	13.0	20.1	15.0	14.5	15.6	22.1	17.4	13.2	14.3	21.1	**16.2**	3.9	4.1	6.4	4.8	4.7	4.9	7.1	5.6	4.3	4.5	6.8	**5.2**
W_6	6.1	7.0	12.3	8.5	7.6	8.5	14.1	10.0	6.8	7.7	13.2	**9.2**	2.0	2.2	3.5	2.6	2.4	2.7	4.0	3.0	2.2	2.4	3.7	**2.8**
W_7	0.2	0.3	0.6	0.4	0.3	0.5	0.6	0.5	0.3	0.4	0.6	**0.4**	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**0.1**
W_8	20.3	21.2	29.9	23.8	22.3	23.3	30.8	25.5	21.3	22.3	30.4	**24.7**	6.3	6.2	9.8	7.4	6.9	6.7	10.0	7.9	6.6	6.4	9.9	**7.7**
Mean	7.0	7.7	11.9	-	8.1	8.9	13.1	-	**7.5**	**8.3**	**12.5**	-	2.2	2.3	3.7	-	2.5	2.7	4.0	-	**2.4**	**2.5**	**3.9**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	0.2		0.8		0.3		1.4		0.2		**0.9**		0.1		0.3		0.1		0.4		0.1		**0.3**	
W	0.4		1.2		0.5		1.4		0.4		**1.1**		0.3		0.7		0.3		0.8		0.2		**0.7**	
W at F	0.7		2.1		0.8		2.4		0.7		**1.9**		0.4		1.3		0.5		1.3		0.4		**1.2**	
F X W	0.7		2.1		0.9		2.5		0.7		**1.9**		0.4		1.2		0.4		1.3		0.4		**1.2**	

Table 4.34: Potassium uptake (kg ha^{-1}) by wild oat as influenced by fertilizer levels and wild oat management treatments in wheat

WMT	Potassium uptake (kg ha^{-1})											
	2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	3.8	4.6	10.8	6.4	5.2	6.4	12.5	8.0	4.5	5.5	11.7	**7.2**
W_2	13.9	15.7	24.1	17.9	16.7	18.5	28.2	21.1	15.3	17.1	26.2	**19.5**
W_3	1.3	2.0	2.4	1.9	1.5	1.7	2.2	1.8	1.4	1.9	2.3	**1.8**
W_4	28.5	30.9	41.8	33.7	31.7	35.0	47.4	38.0	30.1	32.9	44.6	**35.9**
W_5	33.9	35.3	47.6	39.0	41.0	42.2	52.6	45.3	37.5	38.8	50.1	**42.1**
W_6	16.6	19.3	28.8	21.6	20.8	23.3	33.0	25.7	18.7	21.3	30.9	**23.6**
W_7	0.5	0.9	1.5	1.0	0.8	1.2	1.6	1.2	0.7	1.1	1.6	**1.1**
W_8	54.4	56.4	67.6	59.5	59.7	61.5	69.5	63.5	57.1	58.9	68.6	**61.5**
Mean	19.1	20.6	28.1	-	22.2	23.7	30.9	-	**20.7**	**22.2**	**29.5**	-

	2015-16 SEm±	2015-16 CD at 5%	2016-17 SEm±	2016-17 CD at 5%	Pooled SEm±	Pooled CD at 5%
F	0.4	1.5	0.6	2.4	0.2	**0.9**
W	0.9	2.5	1.0	2.9	0.7	**2.0**
W at F	1.5	4.3	1.8	5.1	1.2	**3.0**
F X W	1.5	4.2	1.8	5.1	1.2	**2.5**

4.4.5.3 Potassium uptake by wild oat

Significantly higher mean potassium uptake by wild oat was obtained with 120 % RDF (29.4 kg ha^{-1}). Significantly lower potassium uptake by wild oat was observed with the application of RDF (20.6 kg ha^{-1}) which was on par with the application of 110 % RDF (22.2 kg ha^{-1}) (Table. 4.34).

Weed free (1.1 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (1.8 kg ha^{-1}) recorded significantly lower potassium uptake by wild oat compared to rest of the treatments, but were statistically at par with each other. Significantly higher potassium uptake by wild oat was documented in weedy check (61.5 kg ha^{-1}) than all other treatments, followed by pendimethalin @ 1.5 kg ha^{-1} (42.1 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (35.8 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly lower potassium uptake by wild oat (7.2 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (19.5 kg ha^{-1}) but was significantly higher than the pinoxaden @ 50 g ha^{-1} and weed free condition.

The interaction effect of fertilizer levels and weed management treatments was significant with respect to potassium uptake by wild oat. Significantly higher potassium uptake by wild oat was recorded with 120 % RDF in weedy check (68.5 kg ha^{-1}) compared to rest of the treatments. Application of RDF with weed free situation resulted in significantly lower Potassium uptake by wild oat (0.6 kg ha^{-1}) which was on par with the F_1W_3 ,F_2W_3, F_3W_3, F_2W_7 and F_3W_7.

4.5 Chemical properties and nutrient status of soil after harvest of wheat crop

4.5.1 Chemical properties of the soil after harvest of wheat crop

The data on soil organic carbon, electrical conductivity and soil pH after harvest of wheat as influenced by fertilizer levels and wild oat management treatments in wheat are presented in (Table. 4.35) .

4.5.1.1 Organic carbon (%)

The different fertilizer levels and wild oat management treatments failed to produce significant variation in organic carbon of soil (Table. 4.35).

4.5.1.2 Electrical conductivity (dSm^{-1})

The different fertilizer levels and wild oat management treatments failed to produce significant variation in electrical conductivity of soil (Table. 4.35).

4.5.1.3 pH

The different fertilizer levels and wild oat management treatments failed to produce significant variation in electrical conductivity of soil (Table. 4.35).

Table 4.35: Soil chemical properties after harvest of the crop as influenced by fertilizer levels and wild oat management treatments in wheat

Treatments	pH			EC (dsm^{-1})			Organic carbon (%)		
F.L	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
F_1	7.51	7.53	7.52	0.52	0.59	0.55	0.44	0.43	0.44
F_2	7.50	7.51	7.51	0.50	0.55	0.52	0.43	0.43	0.43
F_3	7.49	7.52	7.50	0.49	0.53	0.51	0.43	0.42	0.43
SEm±	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Wild oat management treatments (W)									
W_1	7.50	7.50	7.50	0.52	0.54	0.53	0.44	0.44	0.44
W_2	7.50	7.51	7.51	0.49	0.55	0.52	0.44	0.43	0.44
W_3	7.49	7.50	7.50	0.49	0.55	0.52	0.43	0.43	0.43
W_4	7.52	7.52	7.52	0.50	0.56	0.53	0.43	0.43	0.43
W_5	7.49	7.53	7.51	0.50	0.54	0.44	0.44	0.43	0.43
W_6	7.48	7.50	7.49	0.51	0.57	0.54	0.43	0.42	0.43
W_7	7.49	7.55	7.52	0.49	0.57	0.53	0.43	0.42	0.42
W_8	7.52	7.54	7.53	0.52	0.55	0.54	0.43	0.42	0.43
SEm±	0.02	0.01	0.01	0.03	0.03	0.02	0.01	0.01	0.01
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.5.2 Soil nutrient status after harvest

The data on available nutrients in the soil *viz*., nitrogen, phosphorus and potassium after harvest of the crop as influenced by fertilizer levels and herbicides on wild oat management in wheat are presented in Table 4.36 and 4.37.

4.5.2.1 Soil nitrogen status after harvest of wheat

Available mean nitrogen after harvest of crop was significantly higher with the application of 120 % RDF (202.1 kg ha^{-1}) than other treatments. Significantly lower available nitrogen was recorded with the application of RDF (166.1 kg ha^{-1}).

Among the wild oat management treatments, weed free (156.1 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (157.5 kg ha^{-1}) recorded significantly lower available nitrogen compared to rest of the treatments.

4.5.2.2 Soil phosphorus status after harvest of wheat

Available phosphorus after harvest of crop was significantly higher with the application of 120 % RDF (28.8 kg ha^{-1}) compared to other levels of fertilizer. Significantly lower available phosphorus after harvest was recorded with the application of RDF (16.1 kg ha^{-1}).

Table 4.36: Soil nitrogen and phosphorus status after harvest as influenced by fertilizer levels and wild oat management treatments in wheat at field condition

WMT	Nitrogen (kg ha^{-1})												Phosphorus (kg ha^{-1})											
	2015-16				2016-17				Pooled				2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	166.1	186.0	212.9	188.3	150.2	167.2	194.4	170.6	158.2	176.6	203.6	**179.5**	17.2	24.0	32.3	24.5	15.1	21.3	30.0	22.1	16.1	22.6	31.2	**23.3**
W_2	178.0	195.5	222.8	198.8	159.5	177.6	201.0	179.4	168.8	186.6	211.9	**189.1**	18.2	24.5	32.7	25.1	15.4	21.7	29.7	22.3	16.8	23.1	31.2	**23.7**
W_3	152.8	166.2	176.0	165.0	138.0	151.2	160.6	149.9	145.4	158.7	168.3	**157.5**	13.8	19.3	25.4	19.5	11.4	17.0	21.5	16.6	12.6	18.1	23.4	**18.1**
W_4	189.5	206.0	226.3	207.3	170.8	189.9	208.8	189.8	180.2	198.0	217.6	**198.6**	19.7	25.6	31.9	25.7	16.7	23.3	29.7	23.2	18.2	24.4	30.8	**24.5**
W_5	188.3	207.3	225.0	206.9	171.1	189.1	208.0	189.4	179.7	198.2	216.5	**198.1**	19.1	25.7	31.4	25.4	16.3	22.9	29.4	22.9	17.7	24.3	30.4	**56.7**
W_6	184.1	201.7	223.8	203.2	164.4	182.4	206.4	184.4	174.3	192.0	215.1	**193.8**	19.4	25.6	32.8	25.9	16.3	22.7	30.4	23.2	17.8	24.2	31.6	**24.5**
W_7	150.8	164.0	175.2	163.4	136.5	150.3	160.2	149.0	143.7	157.1	167.7	**156.2**	13.5	19.0	25.0	19.2	11.1	16.7	21.2	16.3	12.3	17.8	23.1	**17.8**
W_8	186.4	206.1	222.5	205.0	171.9	189.7	209.4	190.3	179.1	197.9	215.9	**197.7**	17.9	25.0	29.6	24.1	16.0	22.8	28.3	22.4	16.9	23.9	28.9	**23.2**
Mean	174.5	191.6	210.6	-	157.8	174.7	193.6	-	**166.2**	**183.1**	**202.1**	-	17.3	23.6	30.1	-	14.8	21.0	27.5	-	**16.1**	**22.3**	**28.8**	-
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
F	7.9		23.1		7.8		24.7		6.8		**17.5**		0.3		1.1		0.2		0.8		0.2		**0.6**	
W	2.0		5.8		2.0		5.6		2.7		**5.0**		0.5		1.4		0.5		1.5		0.4		**1.2**	
W at F	3.5		NS		3.4		NS		3.0		**8.6**		0.8		NS		0.9		NS		0.7		**NS**	
F X W	3.4		NS		3.4		NS		2.9		**8.1**		0.8		NS		0.9		NS		0.7		**NS**	

Table 4.37: Soil nutrient status (Potassium) after harvest as influenced by fertilizer levels and wild oat management treatments in wheat at field condition

WMT	Potassium (kg ha^{-1})											
	2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	194.7	207.1	238.5	213.5	172.3	181.7	201.9	185.3	183.5	194.4	220.2	**199.4**
W_2	202.3	210.3	239.4	217.3	175.7	184.8	199.9	186.8	189.0	197.5	219.6	**202.1**
W_3	180.2	180.4	176.8	179.1	140.3	140.4	136.1	138.9	160.2	160.4	156.4	**159.0**
W_4	218.2	226.0	237.8	227.3	188.6	200.1	209.5	199.4	203.4	213.1	223.6	**213.4**
W_5	212.2	223.7	233.0	223.0	182.7	194.6	208.3	195.2	197.4	209.1	220.7	**209.1**
W_6	210.9	219.1	232.3	220.8	185.3	194.6	213.0	197.6	198.1	206.9	222.7	**209.2**
W_7	175.6	178.1	171.4	175.1	139.4	137.6	135.0	137.3	157.5	157.9	153.2	**156.2**
W_8	205.1	213.0	222.3	213.5	176.6	186.8	199.0	187.5	190.9	199.9	210.7	**200.5**
Mean	199.9	207.2	218.9	-	170.1	177.6	187.8	-	**185.0**	**192.4**	**203.4**	**-**

	2015-16 SEm±	2015-16 CD at 5%	2016-17 SEm±	2016-17 CD at 5%	Pooled SEm±	Pooled CD at 5%
F	1.7	6.5	1.7	6.8	1.5	**5.7**
W	2.7	7.8	2.8	7.9	2.1	**6.0**
W at F	4.7	13.5	4.8	13.7	3.6	**10.3**
F X W	4.7	13.5	4.8	13.7	3.7	**10.5**

Plate 1a: Clodinafop @ 60 g ha^{-1}, in RDF

Plate 1b: Clodinafop @ 60 g ha^{-1}, in 110 % RDF

Plate 1c: Clodinafop @ 60 g ha^{-1}, in 120 % RDF

Plate 1d: Metribuzin @ 175 g ha^{-1}, in RDF

Plate 1e: Metribuzin @ 175 g ha^{-1}, in 110 % RDF

Plate 1f: Metribuzin @ 175 g ha^{-1}, in 120 % RDF

Plate 1: Comparison of clodinafop @ 60 g ha^{-1} and metribuzin @ 175 g ha^{-1} efficacy, at different fertilizer levels under field conditions (a to f).

Plate 2a: Pinoxaden @ 50 g ha^{-1}, in RDF

Plate 2b: Pinoxaden @ 50 g ha^{-1}, in 110 % RDF

Plate 2c: Pinoxaden @ 50 g ha^{-1}, in 120 % RDF

Plate 2d: Sulfosulfuron @ 25 ha^{-1}, in RDF

Plate 2e: Sulfosulfuron @ 25 ha^{-1}, in 110 % RDF

Plate 2f: Sulfosulfuron @ 25 ha^{-1}, in 120 % RDF

Plate 2: Comparison of pinoxaden @ 50 g ha^{-1} and sulfosulfuron @ 25 ha^{-1} efficacy, at different fertilizer levels under field conditions (a to f).

Plate 3a: Pendimathalin @ 1.5 kg ha^{-1} in RDF

Plate 3b: Pendimathalin @ 1.5 kg ha^{-1} in 110 % RDF

Plate 3c: Pendimathalin @ 1.5 kg ha^{-1} in 120 % RDF

Plate 3d: Pendimathalin+ metribuzin @ 1.5 kg ha^{-1} in RDF

Plate 3e: Pendimathalin+ metribuzin @ 1.5 kg ha^{-1} in 110 % RDF

Plate 3f: Pendimathalin+ metribuzin @ 1.5 kg ha^{-1} in 120 % RDF

Plate 3: Comparison of Pendimathalin @ 1.5 kg ha^{-1} and Pendimathaline+ metribuzin @ 1.5 kg ha^{-1}, at different fertilizer levels under field conditions (a to f).

Plate 4a: Weed free in RDF

Plate 4 b: Weed free in 110 % RDF

Plate 4c: Weed free in 120 % RDF

Plate 4d: Weed check in RDF

Plate 4e: Weed check in 110 % RDF

Plate 4f: Weed check in 120 % RDF

Plate 4: Comparison of weed free and weedy, at different fertilizer levels under field conditions (a to f).

Weed free (17.7 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (18.1 kg ha^{-1}) recorded significantly lower available mean phosphorus in soil after harvest of crop compared to rest of the treatments, but were statistically at par with each other. Significantly higher available phosphorus after harvest of crop was documented in pendimethalin + metribuzin @ 1.5 kg ha^{-1} (24.5 kg ha^{-1}). Which was statistically at par with each other except pinoxaden @ 50 g ha^{-1} (Table. 4.36) and free condition.

4.5.2.3 Soil potassium status after harvest of wheat

Available mean potassium after harvest of crop was significantly higher with the application of 120 % RDF (203.4 kg ha^{-1}) when compared with RDF (185 kg ha^{-1}) and 110 % RDF (192.4 kg ha^{-1}) (Table. 4.37).

Weed free (156.2 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (159.1 kg ha^{-1}) recorded significantly lower available potassium after harvest of crop compared to rest of the treatments, but were statistically at par with each other. Significantly higher available potassium after harvest of crop was documented in metribuzin @ 175 g ha^{-1} (213.3 kg ha^{-1}), followed by pendimethalin + metribuzin @ 1.5 kg ha^{-1} (209.2), pendimethalin @ 1.5 kg ha^{-1} (209.1 kg ha^{-1}) and sulfosulfuron @ 25 g ha^{-1} (202.1 kg ha^{-1}) significantly higher than all other treatments.

4.6 Economic analysis of wheat cultivation

The data on economics of wheat *viz.*, cost of cultivation, gross returns, net returns and B:C as influenced by fertilizer levels and herbicides on wild oat management in wheat are presented in Tables 4.38 and 4.39.

4.6.1 Cost of cultivation

Lower mean cost of cultivation (Rs. 56,908) was with the application of RDF when compared with 120 % RDF (Rs. 58, 324), among the fertilizer levels (Table. 4.38). RDF recorded 2.42 % and 1.08 % lower cost of cultivation than the 120 % and 110 % RDF, respectively.

Among the wild oat management treatments, weed free (Rs. 61,502) recorded higher cost of cultivation when compared with rest of the treatments, whereas, least was documented in metribuzin @ 175 g ha^{-1}(Rs. 55,542). Weedy recorded higher cost of cultivation (Rs. 59,111) when compared with pinoxaden @ 50 g ha^{-1} (Rs. 56,929) all other herbicides have lower cost of cultivation than weedy check.

The interaction effect of fertilizer levels and wild oat management treatments, the higher cost of cultivation was recorded with the combination of 120 % RDF with weed free situation (Rs. 63,370) compared to rest of the treatments followed by 110 % RDF with weed free (Rs. 61,070) and weed free situation in RDF (Rs. 60,065). In interactions the lowest cost of cultivation recorded in RDF + metribuzin @ 175 g ha^{-1} (Rs. 54, 969).

4.6.2 Gross returns

Lower gross returns was observed with the application of 120 % RDF (Rs. 91,185) whereas higher gross returns was obtained with RDF (Rs. 1,01, 051) which was similar with the application of 110 % RDF (Rs. 98,671). RDF recorded 10.82 % and 2.4 % higher gross returns than the 120 % and 110 % RDF, respectively.

Weed free (Rs. 1, 25, 074) and application of pinoxaden @ 50 g ha^{-1} (Rs. 1, 24, 075) recorded higher gross returns compared to rest of the treatments, but were no much difference among them. Lower gross returns was noticed in weedy check (62,018 Rs) followed by pendimethalin @ 1.5 kg ha^{-1} (Rs. 82,174) and metribuzin @ 175 g ha^{-1} (Rs. 83,939).

The interaction effect of fertilizer levels and wild oat management treatments differ with respect to gross returns of wheat. Higher gross returns was recorded with the combination of 120 % RDF with weed free situation (Rs. 1, 29, 069) compared to rest of the treatment combinations, followed by 110 % RDF with weed free situation (Rs. 1, 23, 366) and weed free in RDF (Rs. 1, 22, 786). Significantly lower gross returns were recorded with weedy check situation (Rs. 54, 607). Gross return of wheat crop in weed free situation and pinoxaden @ 50 g ha^{-1} was nearly similar at all the fertilizer levels but numerically high in 120 % RDF. Whereas, it was reverse in case of rest of the treatments.

4.6.3 Net returns

Lower net returns were recorded with the application of 120 % RDF (Rs. 34,196) whereas higher net returns were documented with RDF (Rs. 45,786) which was similar to the application of 110 % RDF (Rs. 42,703) (Table.4.39).

Among the wild oat management treatments, lower net returns was observed in weedy check (15, 015 Rs.) followed by pendimethalin @ 1.5 kg ha^{-1} (Rs. 24,694) and metribuzin @ 175 g ha^{-1} (Rs. 28,397). Weed free (Rs. 63,572) and application of pinoxaden @ 50 g ha^{-1} (Rs. 67,145) recorded higher net returns compared to rest of the treatments.

The interaction effect of fertilizer levels and wild oat management treatments varied with respect to net returns of wheat. Higher net returns was recorded with the combination of 120 % RDF with pinoxaden (Rs. 70,599) and 110 % RDF with pinoxaden (Rs. 65, 926) compared to all other treatment combinations, followed by 120 % RDF with weed free situation (Rs. 65,699) and pinoxaden in RDF (Rs. 64,910). A lowest net return was recorded with 120 % RDF with weedy check situation (Rs. 5,604) with decrease in fertilizer levels the net return of the crop also increased.

Table 4.38: Cost of cultivation and gross returns (Rs.) of wheat as influenced by fertilizer levels and wild oat management treatments

WMT	**Cost of cultivation (Rs.)**											
	2015-16				**2016-17**				**Pooled**			
	Fertilizer levels (F)				**Fertilizer levels (F)**				**Fertilizer levels (F)**			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	55,423	55,995	56,567	55,995	55,594	56,169	56,744	56,169	55,509	56,082	56,655	**56,082**
W_2	55,418	55,990	56,562	55,990	55,589	56,164	56,739	56,164	55,504	56,077	56,650	**56,077**
W_3	56,269	56,840	57,412	56,840	56,444	57,019	57,594	57,019	56,356	56,930	57,503	**56,930**
W_4	54,885	55,457	56,029	55,457	55,054	55,628	56,203	55,628	54,969	55,543	56,116	**55,543**
W_5	56,817	57,389	57,961	57,389	56,995	57,570	58,145	57,570	56,906	57,479	58,053	**57,479**
W_6	57,326	57,898	58,470	57,898	57,507	58,082	58,657	58,082	57,417	57,990	58,563	**57,990**
W_7	59,969	60,971	63,265	61,402	60,163	61,170	63,475	61,602	60,066	61,071	63,370	**61,502**
W_8	57,447	58,019	58,591	58,019	59,629	60,203	60,778	60,203	58,538	59,111	59,685	**59,111**
Mean	56,694	57,320	58,107	-	57,122	57,751	58,542	-	**56,908**	**57,535**	**58,324**	-
WMP	**Gross returns (Rs.)**											
	2015-16				2015-16				2015-16			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	1,05,119	1,00,366	86,671	97,385	1,22,563	1,20,884	1,06,824	1,16,757	11,3841	1,10,625	96,747	**1,07,071**
W_2	95,289	9,29,75	77,737	88,667	1,15,506	1,12,810	1,00,315	1,09,544	1,05,398	1,02,892	89,026	**99,105**
W_3	1,13,208	1,14,002	1,20,331	1,15,847	1,29,325	1,31,710	1,35,873	1,32,303	1,21,267	1,22,856	1,28,102	**1,24,075**
W_4	80,078	77,774	66,767	74,873	10,1056	94,249	83,711	93,005	90,567	86,011	75,239	**83,939**
W_5	79,838	75,461	66,487	73,928	96,958	92,467	81,831	90,419	88,398	83,964	74,159	**82,174**
W_6	87,833	85,051	73,175	82,020	1,09,473	1,06,364	91,889	1,02,575	98,653	95,707	82,532	**92,297**
W_7	1,14,386	1,15,115	1,21,161	1,16,887	1,31,186	1,31,618	1,36,976	1,33,260	1,22,786	1,23,366	1,29,069	**1,25,074**
W_8	73,772	68,915	59,141	67,276	87,445	84,050	71,435	80,977	80,608	76,482	65,288	**74,126**
Mean	93,690	91,207	83,934	-	1,11,689	1,09,269	1,01,107	-	**1,02,690**	**1,00,238**	**92,520**	-

Table 4.39: Net returns and B:C (Rs.) of wheat as influenced by fertilizer levels and wild oat management treatments

WMT	**Net returns (Rs.)**											
	2015-16				2016-17				Pooled			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	49,696	44,371	30,104	41,390	66,969	64,715	50,080	60,588	58,332	54,543	40,092	**50,989**
W_2	39,872	36,985	21,175	32,677	59,917	56,646	43,576	53,380	49,894	46,815	32,375	**43,028**
W_3	56,940	57,162	62,919	59,007	72,881	74,691	78,279	75,284	64,910	65,926	70,599	**67,145**
W_4	25,193	22,317	10,738	19,416	46,002	38,621	27,508	37,377	35,598	30,469	19,123	**28,397**
W_5	23,021	18,072	8,526	16,540	39,963	34,897	23,687	32,849	31,492	26,484	16,106	**24,694**
W_6	30,507	27,153	14,705	24,121	51,965	48,282	33,232	44,493	41,236	37,717	23,968	**34,307**
W_7	54,417	54,143	57,896	55,485	71,023	70,448	73,501	71,658	62,720	62,296	65,699	**63,572**
W_8	16,324	10,896	5,550	9,257	27,817	23,847	10,657	20,773	22,070	17,371	5,604	**15,015**
Mean	36,996	33,887	25,827	-	54,567	51,518	42,565	-	**45,782**	**42,703**	**34,196**	-
WMT	**B:C**											
	2015-16				2015-16				2015-16			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
W_1	1.90	1.79	1.53	1.74	2.20	2.15	1.88	2.08	2.05	1.97	1.71	**1.91**
W_2	1.72	1.66	1.37	1.58	2.08	2.01	1.77	1.95	1.90	1.83	1.57	**1.77**
W_3	2.01	2.01	2.10	2.04	2.29	2.31	2.36	2.32	2.15	2.16	2.23	**2.18**
W_4	1.46	1.40	1.19	1.35	1.84	1.69	1.49	1.67	1.65	1.55	1.34	**1.51**
W_5	1.41	1.31	1.15	1.29	1.70	1.61	1.41	1.57	1.55	1.46	1.28	**1.43**
W_6	1.53	1.47	1.25	1.42	1.90	1.83	1.57	1.77	1.72	1.65	1.41	**1.59**
W_7	1.91	1.89	1.92	1.90	2.18	2.15	2.16	2.16	2.04	2.02	2.04	**2.03**
W_8	1.28	1.19	1.01	1.16	1.47	1.40	1.18	1.35	1.38	1.29	1.09	**1.25**
Mean	1.65	1.59	1.44	-	1.96	1.89	1.73	-	**1.80**	**1.74**	**1.58**	-

4.6.4 B:C

Higher B:C was obtained with RDF (1.78) which was similar to the application of 110 % RDF (1.72). Whereas lowest B:C among fertilizer levels was observed in the application of 120 % RDF (1.56).

Among the wild oat management treatments, weed free (2.03) and application of pinoxaden @ 50 g ha^{-1} (2.18) recorded higher B:C compared to rest of the treatments. Lower B:C was documented in weedy check (1.03) followed by pendimethalin @ 1.5 kg ha^{-1} (1.43) and metribuzin @ 175 g ha^{-1} (1.51). Pendimethalin + metribuzin recorded higher B:C when compared with alone pendimethalin and metribuzin application. *i.e.* 5.2 % and 11.1 % increase in B:C over alone application of herbicides Table 4.39.

The interaction effect of fertilizer levels and wild oat management treatments differ with respect to B:C of wheat. Higher B:C was recorded with the combination of 120 % RDF with pinoxaden @ 50 g ha^{-1} and weed free situation (2.23 and 2.04), compared to all other treatment combinations, followed by 110 % RDF with pinoxaden and weed free situation (2.16 and 2.02) and weed free situation and pinoxaden in RDF (2.15 and 2.04). Lower B:C was recorded with weedy check situation (1.09) in 120 % RDF, followed by weedy in 110 % RDF (1.29) and weedy check in RDF (1.38).

4.7 Screen house studies on wild oat

The data on wild oat *viz.* emergence, plant height of wild oat, mortality per cent, wild oat dry weight, weed control efficiency, 50 % spike emergence, 50 % flowering of wild oat, panicle length, grains per panicle and test weight as influenced by fertilizer levels and wild oat management treatments in pot studies are presented.

4.7.1 Emergence percentage (%)

Emergence for the fertilizer levels were observed in the laboratory in petri plates as well as in pots in screen house. Higher emergence per cent was recorded in 120 % RDF (77.3 %) and compared to lower dose of fertilizer. (Fig. 9).

Among the wild oat management treatments, lower emergence per cent was recorded with pendimethalin + metribuzin (1.5 kg ha^{-1}) (7.13 %) followed by pendimethalin 1.5 kg ha^{-1} (72.14 %). All other treatments showed similar results in emergence, except, pendimethalin and pendimethalin + metribuzin applied as pre emergence. The interaction effects were found to be non-significant with relation to emergence.

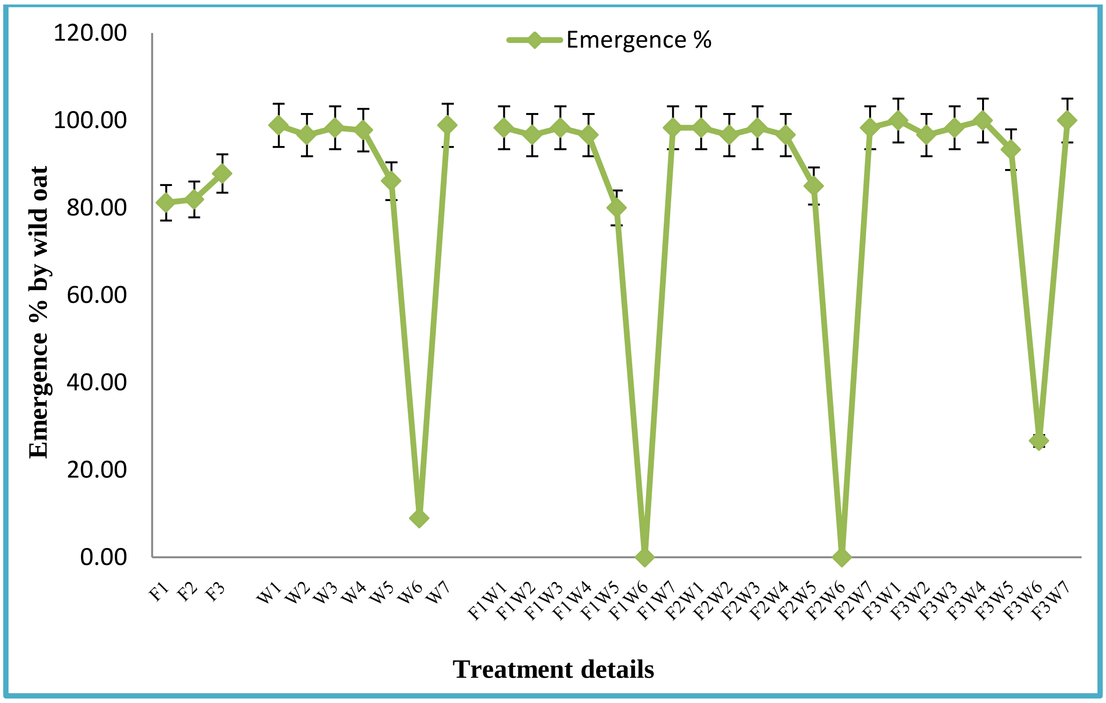


Fig 9:**Emergence per cent (%) as influenced by fertilizer levels and herbicides on wild oat management in wheat**

4.7.2 Plant height (cm)

Plant height of wild oat at 60, 90, 120 and at harvest varied significantly due to fertilizers levels and wild oat management treatments (Table 4.40 and 4.41). The data on wild oat height at 30 DAS was not significantly influenced by fertilizer levels and their interaction, but significantly differed with only wild oat management treatments. At 60, 90, 120 DAS and at harvest, among the fertilizer levels; pooled data indicate, significantly lower wild oat height was recorded with the application of RDF (28.6, 39.1, 46.6 and 48.3 cm, respectively) which was on par with the application of 110 % recommended dose of fertilizer (30.4, 43.6, 55.3 and 57.7 cm, respectively. Wild oat height was significantly higher with the application of 120 % RDF (41.2, 60.1, 74.9 and 77.2 cm, respectively) in all growth stages.

Lower wild oat height was resulted in pre-emergence herbicides compared with the post-emergent herbicides (Table 4.40). Significantly lower wild oat height at 30 DAS was resulted with pendimethalin + metribuzin @ 1.5 kg ha^{-1} (1.3 cm) followed by pendimethalin @ 1.5 kg ha^{-1} alone (32.4 cm). At 60, 90, 120 DAS and at harvest, among the wild oat management treatments; significantly higher wild oat height was recorded in weedy (70.9, 103.9, 123.9 and 128 cm, respectively) followed by pendimethalin @ 1.5 kg ha^{-1} (53.1, 75.4, 95.6 and 99.5 cm, respectively) and metribuzin @ 175 g ha^{-1} (50.3, 71.9, 95.6 and 99.5 cm, respectively). Clodinafop @ 60 g ha^{-1} recorded significantly lower wild oat height (13.6, 25.8, 33.1 and 34.9 cm, respectively) when compared with sulfosulfuron @ 25 g ha^{-1} (39.8, 45.9, 53.6 and 55.3 cm, respectively) though was significantly higher than the pinoxaden @ 50 g ha^{-1}. Pendimethalin + metribuzin 1.5 kg ha^{-1} (3.4, 5.3, 7.4 and 8.4 cm, respectively) and application of pinoxaden @ 50 g ha^{-1} (2.7, 4.9, 7.1 and 7.3 cm, respectively) recorded significantly lower wild oat height compared to all other treatments statistically similar but all the interactions were found to be non-significant with relation to wild oat height at all the growth stages of the wheat.

4.7.3 Mortality of wild oat (%)

Mortality % was recorded with 45 and 60 DAS in pots having wild oat plants (Table 4.4). Significantly less wild oat mortality was recorded with the application of 120 % RDF (54.4 and 53.2 %). Wild oat mortality was significantly more with the application of RDF (61.1 and 62.1 %) which was at par with the application of 110 % RDF (59.6 and 59.9 %) in both 45 and 60 DAS. The reduction in mortality % with the application of higher dose of fertilizer *i.e.*, 120 % RDF was the tune of 11.6 % and 14.3 % at 45 and 60 DAS.

Table 4.40: Plant height (cm) of wild oat at 30, 60 and 90 DAS in screen house as influenced by fertilizer levels and wild oat management treatments

Treatments	**30 DAS**			**60 DAS**			**90 DAS**		
F.L (F)	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
F_1	36.5	34.6	**35.6**	29.0	28.1	**28.6**	44.1	34.2	**39.1**
F_2	38.0	36.6	**37.3**	31.1	29.7	**30.4**	45.9	41.4	**43.6**
F_3	40.4	39.2	**39.8**	41.0	41.4	**41.2**	61.6	58.5	**60.0**
SEm±	0.5	1.1	**0.5**	1.3	1.6	**0.8**	3.5	3.4	**2.7**
CD at 5%	NS	NS	**NS**	3.7	4.4	**2.3**	10.0	9.7	**7.7**
Wild oat management treatments (W)									
W_1	45.4	42.7	**44.1**	14.1	13.1	**13.6**	30.4	21.2	**25.8**
W_2	44.3	47.3	**45.8**	40.2	39.3	**39.8**	52.7	39.1	**45.9**
W_3	46.1	46.2	**46.2**	2.8	2.6	**2.7**	4.7	5.1	**4.9**
W_4	45.0	48.6	**46.8**	50.2	50.4	**50.3**	74.3	69.6	**71.9**
W_5	39.2	25.7	**32.4**	52.3	53.8	**53.1**	78.1	72.8	**75.4**
W_6	1.3	1.3	**1.3**	3.2	3.6	**3.4**	5.4	5.2	**5.3**
W_7	46.6	45.9	**46.2**	73.0	68.8	**70.9**	107.8	100.0	**103.9**
SEm±	0.7	1.7	**0.8**	2.0	2.4	**1.2**	5.3	5.2	**4.1**
CD at 5%	**2.1**	**4.8**	**2.4**	**5.7**	**6.7**	**3.5**	**15.2**	**14.8**	**11.8**
F X W	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4.41: Plant height (cm) of wild oat at 120 DAS and at harvest in screen house as influenced by fertilizer levels and wild oat management treatments

Treatments	120 DAS			At harvest		
F.L (F)	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
F_1	49.0	44.3	**46.6**	51.1	45.5	**48.3**
F_2	55.3	55.3	**55.3**	57.2	58.2	**57.7**
F_3	75.9	73.8	**74.9**	79.6	74.9	**77.2**
SEm±	4.5	4.9	**3.7**	4.6	5.1	**3.8**
CD at 5%	12.8	13.9	**10.4**	13.1	14.7	**10.7**
Wild oat management treatments (W)						
W_1	32.2	34.0	**33.1**	33.7	36.1	**34.9**
W_2	56.1	51.1	**53.6**	58.1	52.4	**55.3**
W_3	7.4	6.6	**7.0**	8.0	6.7	**7.3**
W_4	93.6	90.3	**91.9**	94.9	93.4	**94.2**
W_5	97.1	94.0	**95.6**	102.3	96.7	**99.5**
W_6	7.9	7.0	**7.4**	8.8	7.9	**8.4**
W_7	126.1	121.8	**123.9**	132.6	123.4	**128.0**
SEm±	6.8	7.5	**5.6**	7.0	7.8	**5.7**
CD at 5%	19.5	21.3	**15.9**	20.0	22.4	**16.4**
F X W	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4.42: Mortality per cent at 45 and 60 DAS as influenced by fertilizer levels and wild oat management treatments in screen house

Treatments F.L (F)	Mortality (%)					
	45 DAS			60 DAS		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
F_1	60.1 (71.7)	62.2 (73.9)	**61.1 (72.8)**	59.2 (70.4)	65.0 (76.7)	**62.1 (73.6)**
F_2	58.7 (69.8)	60.5 (72.3)	**59.6 (71.1)**	57.7 (68.2)	62.1 (73.8)	**59.9 (71.1)**
F_3	53.8 (63.5)	54.2 (64.7)	**54.0 (64.1)**	50.8 (59.1)	55.6 (66.6)	**53.2 (62.9)**
SEm±	0.93	1.32	**0.81**	0.86	1.39	**0.86**
CD at 5%	2.67	3.77	**2.32**	2.46	3.97	**2.45**
Wild oat management treatments (W)						
W_1	69.3 (86.7)	72.6 (89.6)	**70.9 (88.2)**	65.3 (81.5)	76.7 (92.2)	**71.1 (86.6)**
W_2	59.1 (73.3)	64.3 (80.7)	**61.7 (77.1)**	56.3 (68.9)	70.1 (86.7)	**63.2 (77.7)**
W_3	81.6 (96.4)	80.7 (94.1)	**81.2 (95.2)**	80.9 (95.6)	83.8 (96.7)	**82.3 (96.1)**
W_4	52.1 (62.2)	55.7 (68.1)	**53.9 (65.2)**	51.2 (60.7)	58.4 (72.2)	**54.8 (66.4)**
W_5	50.8 (60)	51.2 (60.7)	**51.0 (60.4)**	47.7 (54.8)	51.4 (61.1)	**49.6 (57.9)**
W_6	89.9 (100)	88.3 (99.3)	**89.1 (99.7)**	89.9 (100)	85.8 (97.8)	**87.9 (98.8)**
W_7	0.00	0.00	**0.00**	0.00	0.00	**0.00**
SEm±	1.43	2.02	**1.24**	1.32	2.13	**1.31**
CD at 5%	4.07	5.75	**3.55**	3.75	6.07	**3.74**
F X W	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*** Original data were subjected to Arc sine transformation and presented in parentheses**

Plate 5: Wild oat with RDF, 110 % RDF and 120 % RDF in screen house

Plate 6a: Control and pendimethalin + metribuzin 1.5 kg ha^{-1} with 100, 110 & 120 %

Plate 6b: Control and pinoxaden 50 g ha^{-1} with 100, 110 & 120% RDF, 14 DAT

Plate 6A: Comparison of pendimethalin + metribuzin 1.5 kg ha^{-1} and pinoxaden 50 g ha^{-1} efficacy with variable fertilizer levels under screen house condition after 14 DAT. (Plate 6a & 6b)

Plate 6c: Control and clodinafop @ 60 g ha^{-1} with 100, 110 & 120% RDF, 14 DAT

Plate 6d: Control and sulfosulfuron @ 25 g ha^{-1} with 100, 110 & 120 % 14 DAT

Plate 6e: Control and pendimethalin @ 1.5 kg ha^{-1} with 100, 110 & 120 RDF, 14 DAT

Plate 6.B: Comparison of clodinafop @ 60 g ha^{-1}, sulfosulfuron @ 25 g ha^{-1} and pendimethalin @ 1.5 kg ha^{-1} efficacy with variable fertilizer levels under screen house condition after 14 DAT. (Plate 6c to 6e)

At 45 and 60 DAS, significantly higher wild oat mortality was recorded in pendimethalin + metribuzin @ 1.5 kg ha^{-1} (89.1 and 87.9 %) followed by pinoxaden @ 50 g ha^{-1} (81.2 and 82.3 %). Clodinafop @ 60 g ha^{-1} recorded significantly higher wild oat mortality (70.9 and 71.04 %) when compared with sulfosulfuron @ 25 g ha^{-1} (61.7 and 63.2 %) though it was significantly lower than the pinoxaden @ 50 g ha^{-1}. Pendimethalin 1.5 kg ha^{-1} (51.4 and 49.3 %) and application of metribuzin @ 175 g ha^{-1} (53.9 and 54.5 %) recorded significantly lower wild oat mortality compared to all other treatments among the wild oat management treatments; but were statistically at par with each other. All the interactions were found to be non-significant with relation to wild oat mortality (Table. 4.42).

4.7.4 Dry weight of wild oat at harvest (g)

Wild oat dry weight at harvest was significantly higher with the application of 120 % RDF (54.6 g) when compared with RDF (35.1 g). Application of 110 % RDF registered dry weight (41.2 g) which was significantly higher than the RDF but significantly lower than the 120 % RDF (Table.4.43).

Significantly higher wild oat dry weight at harvest was recorded in case of weedy check (125.1 g) followed by application of pendimethalin 1.5 kg ha^{-1} (60.3 g) and metribuzin @ 175 g ha^{-1} (50.2 g), recorded significantly lower than the weedy(Table. 4.43). Clodinafop @ 60 g ha^{-1} recorded significantly lower wild oat dry weight at harvest (26.3 g) when compared with sulfosulfuron @ 25 g ha^{-1} (34.5 g) though significantly higher than the pinoxaden @ 50 g ha^{-1}. Significantly lower wild oat dry weight was recorded in pendimethalin + metribuzin @ 1.5 kg ha^{-1} (3.4 g) and pinoxaden @ 50 g ha^{-1} (5.8 g), all other wild oat management treatments. Dry weight of wild oat decreased 36.7 times with pendimethalin + metribuzin @ 1.5 kg ha^{-1} and 21.5 times with pinoxaden @ 50 g ha^{-1} more when compared with weedy check.

4.7.5 Weed control efficiency (%)

WCE at harvest was with the application of RDF (57.66 %) was at par with the application of 110 % RDF (55.88 %) and significantly higher than with application of 120 % RDF (51.05 %).

Significantly higher WCE was recorded in pendimethalin + metribuzin @ 1.5 kg ha^{-1} (86.87 %) as pre emergence application compare to all other treatments (Table. 4.43). Significantly lower WCE at harvest was recorded pendimethalin @ 1.5 kg ha^{-1} (46.24 %) followed by application of metribuzin @ 175 g ha^{-1} (50.88 %). Clodinafop @ 60 g ha^{-1} recorded significantly higher WCE at harvest (63.37 %) when compared with sulfosulfuron @ 25 g ha^{-1} (58.64 %) both were significantly lower than the pinoxaden @ 50 g ha^{-1}.

4.7.6 Spike emergence 50 % and flowering 50 % in wild oat

Among the fertilizer levels; pooled data as well as individual year data indicate that 50 per cent spike emergence and flowering was advanced fast in application of RDF (55.5 and 59.1 DAS) which was at par with the application of 110 % RDF (61.5 and 65.4 DAS). Significantly delayed spike emergence 50 % and flowering 50 % was resulted in application of 120 % RDF (75.3 and 79.7 DAS) as compared to RDF and 110 % RDF (Table.4.44).

Among the wild oat management treatments; delay in spike emergence 50 % and flowering 50 % was recorded with weedy (97.1 and 104.5 DAS) followed by pendimethalin @ 1.5 kg ha^{-1} (96 and 101.8 DAS) and metribuzin @ 175 g ha^{-1} (95.6 and 101.8 DAS) which all were at par with each other. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} (9.6 and 10.1 DAS) as pre emergence application and pinoxaden @ 50 g ha^{-1} (9.1 and 9.5 DAS) as post emergent application showed significant difference with respect to the 50 per cent spike and flower emergence. Clodinafop @ 60 g ha^{-1} recorded significantly faster 50 per cent spike emergence and flowering (51.7 and 53.9 DAS) when compared with sulfosulfuron @ 25 g ha^{-1} (89.8 and 94.8 DAS) pendimethalin, metribuzine and weedy check.

Table 4.43: Dry weight and weed control efficiency in screen house at harvest as influenced by fertilizer levels and wild oat management treatments

Treatments F.L (F)	Dry weight (g)			Wild oat control efficiency (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
F_1	35.5	34.8	**35.1**	58.21 (70.1)	57.11 (68.5)	**57.66 (69.3)**
F_2	41.8	40.7	**41.2**	56.06 (67.1)	55.71 (66.4)	**55.88 (66.8)**
F_3	56.3	52.9	**54.6**	50.99 (59.1)	51.11 (59.4)	**51.05 (59.9)**
SEm±	1.7	1.3	**1.2**	1.00	0.98	**0.85**
CD at 5%	4.7	3.7	**3.3**	2.85	2.79	**2.44**
Wild oat management treatments (W)						
W_1	26.3	26.3	**26.3**	64.02 (80.1)	62.72 (78.7)	**63.37 (79.3)**
W_2	34.3	34.7	**34.5**	59.28 (73.3)	58.00 (71.7)	**58.64 (72.7)**
W_3	6.4	5.2	**5.8**	77.45 (94.9)	78.66 (95.8)	**78.06 (95.4)**
W_4	49.8	50.2	**50.0**	51.70 (61.6)	50.06 (58.7)	**50.88 (60.2)**
W_5	62.1	58.5	**60.3**	46.26 (52.2)	46.22 (52.1)	**46.24 (52.2)**
W_6	3.7	3.2	**3.4**	86.89 (97.6)	86.85 (97.5)	**86.87 (97.6)**
W_7	128.9	121.3	**125.1**	0.00	0.00	**0.00**
SEm±	2.5	2.0	**1.8**	1.52	1.49	**1.31**
CD at 5%	7.2	5.7	**5.0**	4.35	4.26	**3.73**
F X W	NS	NS	NS	NS	NS	NS

*** Original data were subjected to Arc sine transformation and presented in parentheses**

Table 4.44: Spike emergence and flowering of wild oat in screen house as influenced by fertilizer levels and wild oat management treatments

Treatments F.L (F)	**50 % Spike emergence in wild oat**			**50 % Flowering in wild oat**		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
F_1	55.3	55.7	**55.5**	58.8	59.2	**59.0**
F_2	58.8	64.2	**61.5**	62.6	68.3	**65.4**
F_3	75.3	75.4	**75.3**	79.7	79.7	**79.7**
SEm±	4.8	4.1	**4.3**	5.1	4.3	**4.5**
CD at 5%	13.8	11.9	**12.3**	14.6	12.4	**13.1**
Wild oat management treatments (W)						
W_1	51.1	52.3	**51.7**	53.4	54.4	**53.9**
W_2	84.1	95.6	**89.8**	88.6	101.0	**94.8**
W_3	9.0	9.1	**9.0**	9.4	9.6	**9.5**
W_4	95.4	95.7	**95.6**	101.6	102.0	**101.8**
W_5	96.0	96.0	**96.0**	101.6	102.0	**101.8**
W_6	9.7	9.5	**9.6**	10.3	10.0	**10.1**
W_7	96.6	97.6	**97.1**	104.3	104.6	**104.5**
SEm±	7.4	6.4	**6.6**	7.8	6.6	**6.9**
CD at 5%	21.1	18.2	**18.8**	22.3	19.8	**19.8**
F X W	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.7.7 Panicle length of wild oat

Pooled data indicate significantly longer mean panicle with the application of 120 % RDF (19.8 cm) when compared with RDF (10.8 cm) which was at par with the application of 110 % RDF (12.8 cm) (Table.4.46).

Application of pinoxaden @ 50 g ha^{-1} and pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded significantly shorter mean panicle compared to rest of the treatment. Weedy check (25.1cm) recorded significantly longer panicle length, followed by pendimethalin @ 1.5 kg ha^{-1} (21.8 cm) and metribuzin @ 175 g ha^{-1} (21.2 cm). Clodinafop @ 60 g ha^{-1} recorded significantly shorter panicle length (10.7 cm) when compared with sulfosulfuron @ 25 g ha^{-1} (17.8 cm) and but was significantly longer than the pinoxaden @ 50 g ha^{-1} (Table. 4.45) and pendimethalin + metribuzine.

4.7.8 Number of seeds per panicle

Among the fertilizer levels, significantly higher number of seeds per panicle was recorded with the application of 120 % RDF (45.6 cm) when compared with RDF (31.4) followed by application of 110 % RDF (35.7). Increase in mean number of seeds per panicle with 110 % RDF over 100 % RDF was also significant.

Clodinafop @ 60 g ha^{-1} recorded significantly lower number of seeds per panicle. (26.5) when compared with sulfosulfuron @ 25 g ha^{-1} (54.6) but was significantly higher than the pinoxaden @ 50 g ha^{-1} and pendimethalin $_{+}$ metribuzine. Weedy check (61.1) recorded significantly higher number of seeds per panicle which was at par with pendimethalin @ 1.5 kg ha^{-}1, pendimethalin @ 1.5 kg ha^{-1} (57.3) and metribuzin @ 175 g ha^{-1} (55.5) both were at par with each other (Table. 4.45). Application of pinoxaden @ 50 g ha^{-1} (2.9) and pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded (2.1) resulted in significantly lower number of seeds per panicle compared to all other treatments but were statistically at par with each other.

4.7.9 Test weight

Significantly higher test weight was observed with the application of 120 % RDF (16.8 g) over 110 % RDF ((12.7 g) and RDF (10.5 g). Significantly lower test weight (10.5 g) was obtained with the application of RDF which was at par with the application of 110 % RDF (12.7 g).

Table 4.45: Panicle length, seeds panicle^{-1} and test weight of wild oat in screen house as influenced by fertilizer levels and wild oat management treatments

Treatments F.L (F)	Panicle length (cm)			No. of seeds panicle^{-1}			Test weight (g)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
F_1	10.4	11.1	**10.8**	30.5	32.2	**31.4**	10.3	10.7	**10.5**
F_2	12.3	13.4	**12.8**	34.6	36.8	**35.7**	12.4	12.9	**12.7**
F_3	18.8	20.8	**19.8**	44.2	46.9	**45.6**	16.7	16.8	**16.8**
SEm±	1.1	1.3	**1.2**	1.7	2.0	**1.4**	1.0	0.8	**0.8**
CD at 5%	3.1	3.7	**3.4**	4.8	5.9	**3.9**	2.8	2.5	**2.2**
Wild oat management treatments (W)									
W_1	10.1	11.3	**10.7**	25.7	27.3	**26.5**	9.7	10.1	**9.9**
W_2	17.0	18.6	**17.8**	53.3	56.0	**54.6**	16.7	17.5	**17.1**
W_3	1.6	2.3	**2.0**	2.0	3.7	**2.8**	2.1	1.6	**1.8**
W_4	20.0	22.4	**21.2**	54.3	56.6	**55.5**	18.5	19.4	**19.0**
W_5	21.3	22.3	**21.8**	56.3	58.3	**57.3**	19.5	20.3	**19.9**
W_6	2.6	3.3	**3.0**	4.6	5.3	**5.0**	3.3	2.3	**2.8**
W_7	24.4	25.6	**25.0**	59.0	63.3	**61.7**	22.5	23.0	**22.7**
SEm±	1.6	2.0	**1.8**	2.6	3.1	**2.1**	1.5	1.3	**1.2**
CD at 5%	4.8	5.7	**5.2**	7.4	9.0	**6.0**	4.3	3.8	**3.5**
F X W	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Weedy check (22.7 g) recorded significantly higher test weight, which was at par with pendimethalin @ 1.5 kg ha^{-1} (19.9 g) and metribuzin @ 175 g ha^{-1} (19.1 g) significantly higher than all other treatments. Application of pinoxaden @ 50 g ha^{-1} (1.8 g) and pendimethalin + metribuzin @ 1.5 kg ha^{-1} recorded (1.2 g) registered significantly lower test weight compared to all other treatments, but were statistically at par with each other. Clodinafop @ 60 g ha^{-1} recorded significantly lower test weight (9.9 g) when compared with sulfosulfuron @ 25 g ha^{-1} (17.1 g) and but significantly higher than the pinoxaden and pendimethalin + metribuzin (Table. 4.45).

4.7.10 Screen house visual weed control observation

At 45 DAS, significantly higher visual weed control (48.92 %) was obtained with the application of RDF, which was at par with the application of 110 % RDF (45.93 %). Lowest visual weed control was observed with the application of 120 % RDF (41.38 %) (Fig.10).

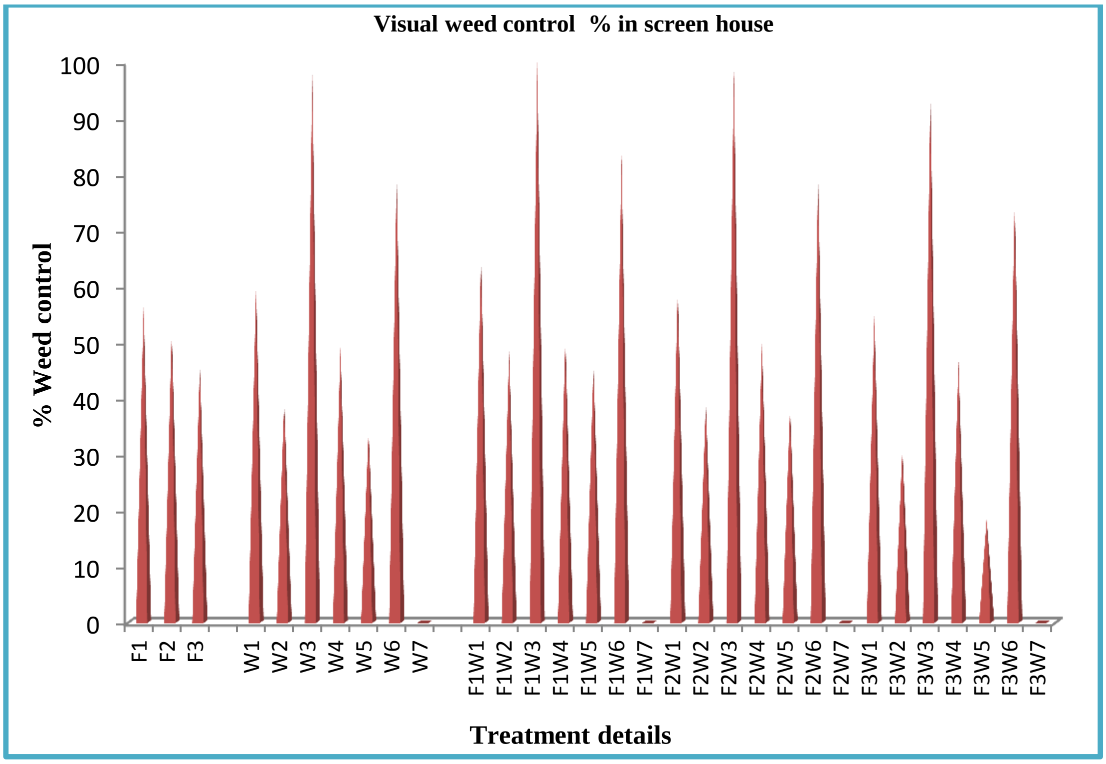


Fig. 10: Effect of fertilizer levels and wild oat management treatments on visual weed control (%) in wheat at screen house

Application of pinoxaden @ 50 g ha^{-1} (85.5 %) and pendimethalin + metribuzin @ 1.5 kg ha^{-1} (63.51 %) recorded significantly higher visual weed control compared to all other treatments. Clodinafop @ 60 g ha^{-1} recorded significantly higher visual weed control (51.04 %) when compared with sulfosulfuron @ 25 g ha^{-1} (38.79 %) but was significantly lower than the pinoxaden @ 50 g ha^{-1} and pendimethalin + metribuzine (Plate: 6.A, and B and 7). Significantly lower weed control was noticed in pendimethalin @ 1.5 kg ha^{-1} (35.02 %).

Plate 7a: Wild oat in 100 % RDF in check, pinoxaden 50 g ha^{-1}, metribuzin175 g ha^{-1}, sulfosulfuron 25 g ha^{-1} and clodinafop 60 g ha^{-1}

Plate 7b: Wild oat in 110 % RDF in check, pinoxaden 50 g ha^{-1}, metribuzin175 g ha^{-1}, sulfosulfuron 25 g ha^{-1} and clodinafop 60 g ha^{-1}

Plate 7c: Wild oat in 120 % RDF in check, pinoxaden 50 g ha^{-1}, metribuzin175 g ha^{-1}, sulfosulfuron 25 g ha^{-1} and clodinafop 60 g ha^{-1}

Plate 7: Effect of levels fertilizers on herbicides efficacy in wild oat under screen house condition after 14 DAT. (Plate: 7a to 7c)

CHAPTER-V

DISCUSSION

The investigation, **"Effect of fertilizer levels and herbicides on wild oat management in wheat"** was carried out during winter seasons of 2015-16 and 2016-17. The results of the investigation have been discussed in this chapter with reasonable scientific basis and logical analysis.

Effect of seasonal conditions on crop performance

Crop growth, development and consequently the grain yield of wheat as influenced by the weather conditions, crop duration and level of weed infestation during cropping seasons of 2015-16 and 2016-17 in discussed below;

5.1 Effect of weather parameters

The most ideal conditions for wheat growth are cool and moist weather during vegetative phase and warm and dry weather during grain formation and maturity. However, balance among different weather parameters must occur during all the growth stages of wheat for timely onset and expression of various yield determining processes.

Weather conditions in wheat season were quite variable during both the years. The actual mean weekly meteorological data during the crop seasons of *rabi* 2015-16 and 2016-17 were recorded at Agricultural meteorological observatory located at the Research Farm of Chaudhary Charan Singh Haryana Agricultural University. The rainfall received during *rabi* seasons of 2015-16 and 2016-17 was 30.5 and 48.7 mm, respectively. One irrigation was saved during second year and rains during March and April resulted in cooler weather at grain filling stage .The average mean weekly maximum temperature in *rabi* 2015-16 varied between 15.3 to 31.5°C and minimum between 3.5 to 15.3°C, while, their corresponding values in *rabi* 2016-17 were 16.9 to 37.2°C and 3.2 to 17.5°C. These pronounced differences in temperature led to the lengthening of reproductive period by 7-8 days in 2016-17 as compared to 2015-16. The duration of grain filling is an important determinant of grain yield in wheat. Longer the duration of grain filling, longer will be the period for photosynthesis of the spike and for translocation of photosynthates. The mean weekly morning and evening relative humidity varied between 83 to 97 and 36 to 75 per cent in *rabi* 2015-16 and between 59 to 100 and 16 to 81 per cent in *rabi* 2016-17, respectively.

5.2 Effect of fertilizer levels on wild oat

Nutrients are one of the most important factors for growth and development of plants and most limiting factor in crop production particularly in irrigated cereal based cropping systems. Blanket recommendation, the most prevailing nutrient management strategy in India could not help in increasing the nutrient use efficiency beyond a limit because of temporal and spatial variability (Singh, 2008). Moreover, farmers have a tendency to apply nutrients in excess of the requirement of crop to avoid risk of deficiency. Overall farmers use about 10.5 to 24.5% higher dose of nutrients in rice–wheat cropping system in Haryana (Singh *et al.*, 2012). However, weeds have naturally good competitive ability; use more water and nutrients as compared to the crop plants (Kaur *et al*., 2016).

With the application of 120 % RDF wild oat density increased by 30.36, 35.11, 37.62 and 36.41 % more than the RDF at 60, 90, 120 DAS and at harvest, respectively (Table. 4.16 and 4.17). When the fertilizer levels were increased from recommended dose it resulted in higher weed occurrence because of higher availability of the nutrients which helps dormant weed seeds to emerge in the soil. These results corroborate with (Mohammad *et al*., 2012; Martin and field, 2014; Woldesenbet *et al*., 2016) because of wild oat, the crop will not be able to utilize the higher nutrients for improvement in the yield levels these results were also observed by (Khan *et al.,* 2009). Martin and field, (2014) also reported that improved fertilization has been found to improve the emergence percentage of wild oat.

The higher density of wild oat at higher nutrient levels was found to enhance wild oat plant height, with increase in plant height, number of leaves per plant will might have increased because of more number of internodes in wild oat (Muhammadi *et al.,* 2016). Availability of nutrients in abundance favors tiller production in wild oat (Saeed *et al*., 2013 and Jafar and abdollah, 2015). Higher number of tillers per plant and higher leaves per tiller in wild oat contributed to higher dry matter accumulation by wild oat (Ponce, 2016). More number of leaves per plant, higher nitrogen and other nutrients improve the chlorophyll content of the leaf and enhanced photosynthates production in wild oat, which led to improved dry matter production in wild oat per meter^{-2} (Banisaeidi *et al*., 2014 and Allyn and john, 2016). Wild oat dry weight was significantly higher at 60, 90, 120 DAS and at harvest of wheat in 120 % RDF (119.43, 134.12, 176.26 and 160.31 g respectively) than RDF (90.51, 99.25, 126.09 and 112.34 g respectively). Saeed *et al. (*2013) and Jafar and abdollah, (2015) also reported that more availability of nutrients favours higher tillers in wild oat which ultimately increase the dry matter of wild oat in the present study. (Tables 4.18, 4.19). This might be due to more nutrients uptake by wild oat at higher levels of fertilizers. These results were in line with the findings of Telavat *et al.,* 2010; Muhammadi *et al.,* 2016; and Khan *et al*., 2015. Dry weight of wild oat was significantly higher with 120 % RDF was *i.e.* 27.11 %, 35.13 %, 39.78 % and 42.13 % at 60, 90, 120 and at harvest over RDF. The per cent increase in weed growth from 60 DAS to harvest indicated good weed growth throughout the crop period. Improved weed growth is one of the symbols of higher total dry matter accumulation; higher dry matter accumulation was indirectly dependent on the higher uptake of the nutrients (Tesfay *et al*., 2016 and Mahendra *et al.,* 2015). Significantly higher nutrient uptake was recorded with 120 % RDF with wild oat (12.51, 3.86 and 29.47 kg ha^{-1} of NPK respectively in pooled data) when compared with RDF (7.52, 235 and 20.66 kg ha^{-1} NPK, respectively) (Table 4.32). Higher dry matter at high fertilizer levels resulted in higher nutrient uptake. These results are in conformity with the findings of Kaur *et al.,* (2016) and Mahendra, *et al*., (2015). Kaur *et al.* (2016) also reported that main reason behind this was the soil nutrient availability and weeds competitive ability and ultimately; use more water and nutrients as compared to the crop plants.

Significantly higher NPK uptake with120 % RDF showed that increased wild oat density and wild oat dry weight resulted in significantly decreased weed control efficiency *i.e.,* (48.31, 48.52, 48.70 and 48.60 % at 60, 90, 120 DAS and at harvest, respectively) when compared with RDF (61.71, 62.02, 59.92 and 61.72 %, respectively) visual control of wild oat with RDF 60.90 % at harvest was significantly better than 120 % RDF, 47.13 %. Similar findings have been reported by Agenbag and Villiers (2009); Anderson., 2003 and Rana *et al*., 2016. Significantly lower weed control efficiency and visual control in 120 % RDF might be due to vigorous growth of wild oat at abundant nutrient level (Singh *et al.,* 1995 and Anderson, 2003). Higher leaf area and higher leaf number was noticed with good weed growth and this has reduced the herbicide efficacy to kill wild oat hence there is lower WCE with relation to the 120 % RDF (Wilson and Peters, 2014). Nutrients will also provoke the second flush of weeds after 60 DAS, which led to poor visual control and significantly lower WCE (Martin and field, 2014; Malik *et al.,* 2013; Kaur *et al.,* 2016 and Harry and James, 2015).

Reproductive characters of wild oat were influenced by the application of nutrients. Application of 120 % RDF resulted in significantly higher panicle length (26.89 cm), grains per panicle (62.01) and test weight (24.82 g) than recommended dose of fertilizer (25.23 cm, 59.35 and 23.64 g respectively). These results are also in accordance with findings of James *et al.*, (2016), Zamani, (2003), Torner *et al*. (2016) and Ortrud *et al*. (2017). The higher length of panicle was the result of higher vigor of weed as well as higher number of vigorous tillers

(Torner *et al*., 2016). The length of panicle directly indicates the number of seeds, and the number of seed holding branches. The test weight of wild oat was higher with 120 % RDF, which may be due to higher accumulation of protein and other associated materials in the seed (Zamani, 2003 and Torner *et al*., 2016). The size of the wild oat seeds were invariably larger in 120 % RDF because of abundance of nutrients and competitive ability of the wild oat. The higher panicle length, number of grains per panicle and test weight might have resulted in higher seed bank in the soil. Which resulted in higher emergence % of wild oat with higher levels of fertilizer in the next crop season (Table. 4.40) These findings are in line with those of Torner *et al*. (2016).

5.3 Effect of fertilizer levels on wheat growth

Growth in plants has various phases which starts with activation of embryo and ends with maturation of seed (yield). The processes involved in plant growth and development are more often limited by deficiency of micro elements in spite of liberal application of major nutrients. The weeds will absorb most of the major and minor nutrients from the soil without much difficulty as they have higher leaf area, longer root systems and low water potential than the crops (Scursoni *et al.,* 2011). In pursuit of yield maximization, the use of imbalanced and excess nutrients has been reported to be the main constraint for currently observed lower yield levels and higher weed dominance in wheat and rice cropping system of northern India (Erenstein *et al.,* 2007).

The higher wild oat density at 120 % RDF reduced growth components of wheat at all the growth stages except plant height. Plant height of wheat increased significantly with the application of 120 % RDF (39.49, 76.36, 82.76 and 84.41 cm at 60, 90, 120 DAS and at harvest, respectively in pooled data) as compared to RDF (36.41, 71.93, 78.23 and 79.61 cm at 60, 90, 120 DAS and at harvest, respectively, Table 4.1). The improvement in plant height due to 120 % RDF application was attributed to proper nourishment of crop for optimum growth. Addition of 120 % RDF helped in release of nutrients for favourable crop growth. Though, increased activity of meristamatic cells and cell elongation with the application 120 % RDF. This may be due to intra competition between crop and weeds, which make plant grow taller in 120 % RDF than RDF. These results corroborate with the findings of Martin and field, 2014; Malik *et al.,* 2013; Mohammadi *et al.,* 2012 and Rana *et al.,* 2016).

The rate of production and number of tillers in wheat are dependent on nutrient supply and weed density. Application of RDF recorded significantly higher number of tillers per mrl (77.28, 79.18, 79.58 and 73.69 tillers per mrl, at 60, 90, 120 DAS and at harvest, respectively in pooled data) as compared to 120 % RDF (70.85, 72.41, 74.15 and 68.39 tillers per mrl, at 60, 90, 120 DAS and at harvest, respectively in pooled data) (Table 4.5 and 4.6). The decrease in number of tillers in 120 % RDF was related to the weed density in the 120 % RDF and weed dry weight. Higher weed density has suppressed the crop, encouraged higher number of tillers in wild oat and their by reduced production of tillers in wheat. These findings are in line with those of Martin and field, (2014), Malik *et al*. (2013), Mohammad *et al*. (2012) and Woldesenbet *et al*. (2016).

Application of RDF recorded significantly higher LAI (4.16, 5.9 and 3.50 at 60, 90 and 120 DAS, respectively) as compared to 120 % RDF. These results are in agreement with the findings of Nasser, (2009) and Gholam *et al.* (2015). Moreover, significantly lower leaf area index with 120 % RDF, was due to higher nutrient up-take by wild oat rather than wheat crop in particular plots (Table. 4.33 and 4.34). These results are in conformity with those of Kaur *et al,* (2016) and Mahendra *et al,* (2015).

The dry matter accumulation is the function of many factors that are known as growth parameters. The variations in dry matter due to treatments could be attributed to the variations in the growth attributing parameters like plant height, total number of tillers, leaf area, leaf area index and crop growth rate. The results on dry matter production differed significantly increased due to RDF application at all the growth stages (Table 4.7 and 4.8). Significantly higher dry matter production was recorded with RDF (52.42, 148.34, 199.70 and 227.43 g mrl^{-1} at 60, 90 and 120 DAS and at harvest in poled data) when compared with 120 % RDF. Application of RDF increased photosynthetic efficiency of wheat which led to higher dry matter production. Significantly lower dry matter accumulation was recorded with 120 % RDF (48.43, 141.28, 191.55 and 220.92 g mrl^{-1} at 60, 90, 120 DAS and at harvest, respectively). This was due to favorable effect of optimum nutrition and higher dry matter distribution in leaf and stem which was due to the higher weed competition for available resources like nutrients and water for wild oat at 120 % RDF due to their higher density and high vigour of wild oat (Table. 4.16 and 4.17). These findings are in line with those of Kaur *et al*. (2016). Significantly higher growth parameters like leaf area, number of tillers, leaf area index and dry matter accumulation in RDF significantly improved the crop growth rate of wheat at all the growth stages of wheat.

5.4 Effect of fertilizer levels on wheat Yield and Nutrient uptake

Economic yield is expressed as function of yield attributes and growth parameters. Yield is affected by both the source and sink and the capacity to translocate photosynthates from one part to another when needed. In cereals, including wheat, the source components are the number of leaves, leaf area per unit ground area, leaf area duration and dry matter of plant whereas the sink are spike number, spikelets/spike, number of grain/spike and 1000-grain weight. The grain yield depends on the synthesis, accumulation and their translocation of photosynthates to earhead. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. The production and translocation of synthesized photosynthates depends upon mineral nutrition available and weed density and competition.

Application of RDF recorded significantly higher mean grain yield (44.72 q ha^{-1}) over 120 % RDF (40.22 q ha^{-1}). Due to higher nutrient uptake and poor WCE by wild oat with 120 % RDF particular fields. These results are in conformity with those of Ahmedvand *et al.* (2016). Significantly lower WCE was noticed in the 120 % RDF over RDF might be due to vigorous growth of wild oat at abundant nutrient level (Singh *et al.,* 1995 and Anderson 2003). Higher leaf area and leaf number and better weed growth might have reduced herbicide efficacy against wild oat leading to lower WCE with 120 % RDF (Sharma *et al.,* 2016). Nutrients might have provoked the second flush of weeds after 45 DAS leading to poor control and significantly lower WCE (Martin and field, 2014 and Kaur *et al.,* 2016).

The mean straw yield of wheat also differed significantly due to fertilizer levels. Significantly higher straw yield was registered under RDF (67.63 q ha^{-1}) than 120 % RDF (61.2 q ha^{-1}) (Table 4.15). The increase in straw yield with RDF was due to increase in vegetative growth as evident from higher dry matter production (Tables. 4.7 and 4.8) and its accumulation in different plant parts like leaves, stem and increased number of tillers (Table. 4.5 and 4.6). Higher straw yield under RDF as compared to 110 % RDF or 120 % RDF. Moreover, straw yield in RDF was also the result of higher number of tillers (10.5 % more) as compared to 120 % RDF which ultimately contributed to the more biological yield and ultimately straw yield.

Application of RDF recorded significantly higher yield components *viz.*, number of productive tillers per m.r.l (69.64), spike length (8.77 cm), number of grains per spike (43.1 1 g), spikelets per spike (19.64) and 1000-grain weight (42.73) as compared to 120 % RDF (Table 4.12 to 4.13). The difference in the performance of yield attributes in different dose of fertilizer might have been due to variations in translocation of photosynthates from vegetative to reproductive parts. Higher grain yield was attributed to higher total dry matter accumulation. These results are in agreement with the earlier findings of Saeed *et al*. (2013).

Nutrient uptake in wheat is the result of nutrient content in grain and straw and the yield of the wheat straw and grain. Since the N, P and K content in different levels of fertilizers was non-significant but it is the straw and grain yield which ultimately influence the nutrient uptake. RDF resulted in higher straw and grain yield of wheat so, ultimately higher nutrient uptake was recorded in RDF. Wheat grown under RDF recorded significantly higher nitrogen, phosphorus and potassium uptake by wheat grain (65.34, 13.39 and 33.66 kg/ha), straw (37.49, 5.30 and 121.68 kg/ha) and total nitrogen uptake (103.32, 18.69 and 155.34 kg/ha) as compared 120 % RDF (Table 4.27 to 4.32) similar results has been reported by Allyn and john, 2016. Significantly higher nitrogen, phosphorus and potassium uptake by wild oat was recorded with 120 % RDF (12.51, 3.86 and 29.47 kg/ha) as compared RDF (Table 4.33 and 4.34). Higher uptake by wild oat indicates the density of the wild oat as well as poor growth of wheat. These results are in conformity with those of Wilson and Peters, 2014 and Sharma *et al.,* 2016.

Growth and yield of crop plants are determined by the presence of sufficient quantities of nutrients for plant uptake. These are decided by soil nutrient status and the soil physical and chemical properties. Higher availability of nutrients to the crop was mainly by the nutrients present in the soil. Nutrients present in the soil and taken up by crop are mainly based on soil pH, EC and organic matter status of the soil. Significantly higher soil nitrogen, phosphorus and potassium was recorded with 120 % RDF (202.09, 28.83 and 203.39 kg ha^{-1}) when compared with RDF. The fertilizers were unutilized in 120 % RDF; which might be due to the poor cop growth. Wild oat showed suppression effect on the crop and made the crop not to utilize the fertilizer in the soil which resulted in poor wheat yield and yield attributes. Nutrients were luxuriously consumed by wild oat in the 120 % RDF hence wheat crop suffered. These findings are similar to Wilson and Peters, 2014.

5.5 Effect of wild oat management treatments on growth components of wheat

Crop growth components like plant height, leaf area, LAI, number of tillers, PAR, CGR and dry matter accumulation were significantly influenced by wild oat management treatments.

Significantly lower plant height (66.3 cm), number of tillers (57.1 mrl^{-1}), LAI (2.82) and PAR (70.8) were obtained in weedy at check at all the growth stages (Tables 4.1 to 4.11). Obviously, this could be due to higher weed dominance offering highest weed competition for space, light, moisture, sun light and nutrients with the crop. Since weed persistence was more from the beginning to the end of the crop growth period, weeds proliferated while the crop starved for space, light and all the factors required for crop growth. All the growth parameters were superior in weed control treatments over unweeded check. Weed free conditions resulted in significantly higher mean plant height (99.8 cm), mean number of tillers (85.1 m.r.l^{-1}), mean LAI (4.1) and mean PAR (86.7) at 120 DAS. The enhancement in crop growth component could be due to less competition by weeds throughout the crop growth period because of effective control. These results are in concomitant with Singh *et al.*, 2013; Jain *et al.,* 2016 and Shyam *et al.,* 2016.

Post emergence application of pinoxaden @ 50 g ha^{-1} was at par with weed free *i.e*, significantly higher mean plant height (99.8 cm), mean number of tillers (85.1 m.r.l^{-1}), mean LAI (4.1) and mean PAR (86.7) followed by application of clodinafop 60 g ha^{-1} (mean plant height (88.6 cm), mean number of tillers (76.8 m.r.l^{-1}), mean LAI (3.6) and mean PAR (74.8). Pinoxaden and clodinafop belongs to ACCase inhibitors which prohibit fatty acid production and membrane development in grassy weeds like wild oat and therefore offered better weed control over all other herbicidal treatments like sulfosulfuron, pendimethalin and metribuzin. Weed free and pinoxaden were superior over weedy check and other herbicidal treatments due to better control of weeds in the early stages effectively which resulted in reduced crop weed competition during the critical period of crop weed competition and helped in better utilization of resources. Similar results have been reported by Katara *et al.* (2015) and Muhammadi *et al.* (2016).

Dry weight accumulation serves as a reliable measure of the relative influence of different treatments on the plant growth and yield attributes. Enhancement in yield of economic part is usually dependent on total dry matter production and its distribution among different parts of the plant. Presence of weeds throughout the growing season caused a reduction of 42-44 % in dry weight by the crop over weed free. The density and dry weight by weeds was highest in weedy plots and therefore dry weight by the crop was least. Dry weight by wheat crop was significantly higher in weed free plots (64.3, 169.3, 221.4 and 248.1 g m.r.l^{-1} at 60, 90, 120 DAS and at harvest respectively) and in plots treated with pinoxaden @ 50 g ha^{-1}(63.6, 168.4, 221.1 and 247.4 g mrl^{-1} at 60, 90, 120 DAS and at harvest, respectively) followed by clodinafop @ 60 g ha^{-1}(56.1, 156.4, 206.2 and 232.9 g mrl^{-1} at 60, 90, 120 DAS and at harvest, respectively). This may be attributed to effective weed control leading to less weed competition. Hence, crop plants could fully utilize the available resources of space, solar radiation, soil moisture and nutrients resulting in enhanced photosynthesis and more dry weight accumulation (Katara *et al*., 2015). Application of pinoxaden was comparable to weed free. Dry weight of crop with the application of PRE herbicide treatments was lower as compared to the POE herbicides. Lower dry matter was accumulated by the crop in plots treated with pendimethalin 1.5 kg ha^{-1} (38.4, 114.8, 173.8, 202.7 g m.r.l^{-1} at 60, 90, 120 DAS and at harvest, respectively) followed by POE application of metribuzin @ 175 g ha^{-1} (42.8, 128.2, 181.8 and 210.9 g per mrl at 60, 90, 120 DAS and at harvest, respectively) due to intense competition for various growth resources from weeds as these were not effectively controlled. These results are in conformity with those of Paighan *et al.* (2015). It is evident from the above discussion that adopting of any weed control practice enhanced the crop growth over unweeded control and for herbicidal treatments POE application was superior over PRE application because of control of weeds at the right stage of crop growth period. Overall, hand weeding was superior over herbicidal treatments because of complete removal of weeds.

5.6 Effect of wild oat management treatments on yield and nutrient uptake by wheat

The yield attributes like number of productive tillers, spike length, grains per spike, spikelets per spike and test weight, seed yield and straw yield were significantly influenced by wild oat management treatments (Tables 4.13 to 4.15).

Crop performance to a great extent is governed by the number of tillers essentially the ear-bearing fertile effective tillers per unit area. It is, therefore, imperative that if effective tillers are higher, then grain yield would be higher. Highest mean number of effective tillers was recorded in weed free plots (81.6 tillers per mrl at harvest) (Table 4.12). Among herbicide treatments, POE application of pinoxaden @ 50 g ha^{-1} produced significantly higher effective tiller number over other herbicide treatments and remained statistically at par with weed free during both the years (81.2 tillers at harvest). Other herbicide treatments also reported more number of effective tillers than PRE pendimethalin or POE metribuzin application. Due to effective weed control, there was less weed density and dry weight in pinoxaden as well as clodinafop treated plots. Hence, crop had favorable growth environment which resulted in higher number of tillers. Whereas, infestation of weeds throughout the crop growing season significantly reduced the number of effective tillers in weedy plots (49 %) which was followed by pendimethalin (34 %) and metribuzin (25 %) relative to the weed free plots due to the intense competition from weeds respectively. Similar results have been reported by Meena and Singh. (2016) and Rana *et al.* (2016).

Weed free and application of pinoxaden @ 50 g ha^{-1} recorded significantly higher yield components when compared with rest of the herbicidal treatments but were similar to each other *viz.*, spike length (9.33 and 9.30 cm), grains per spike (45.4 and 45.3), spikelets per spike (21.9 and 21.7) and test weight (44.3 and 44.2) over weedy check and rest of the herbicide treatments (Tables 4.13 to 4.15). This might be due to the fact that the crop has not experienced nutrient stress at any growth stage. The superior performance of weed free and pinoxaden was due to effective weed control, crop weed competition was eliminated and crop had a better growing environment thus produced more growth parameter and allowed the crop for better establishment and better nutrient uptake, which resulted in better growth parameters such as plant height, leaf area index and dry matter accumulation. Higher production of photosynthates due to sufficient assimilatory area of vigorous plants would have synthesized the carbohydrates and translocated to the reproductive parts such as developing spikes and spikelets which resulted in better grain filling and more grain weight leading to increased yield components. The results are in agreement with the earlier findings of Tesafay *et al.* (2016) and Sharma *et al.* (2016).

Grain yield being a complex character, is the sum of many morphological and biochemical events which occur during the crop growth and development. The yield per unit land area depends on the total bio-productivity and its partitioning into the economically important parts. The grain yield was significantly more in all the herbicide treatments as compared to weedy check (Table 4.15). Significantly higher mean grain yield was recorded with weed free (55.3 q ha^{-1}) which was on par with pinoxaden @ 50 g ha^{-1} (54.8 q ha^{-1}) followed by clodinafop (46.81 q ha^{-1}). This could be ascribed to reduction in weed density and dry weight by the application of herbicides in sequence killing most of the weed cohorts which helped the crop to utilize nutrients, moisture, light and space more efficiently and thus produced more dry weight, more effective tillers, more grains per spike and test weight, hence increased grain yield. These findings are in line with those of Kumar *et al.*, 2013; Balkran and Dhaliwal 2016; Bhagat *et al.*, 2017 and Orturd *et al*., 2017. Weedy check showed significantly lower yield (31.33 q ha^{-1}) among all the wild oat management treatments, followed by pendimethalin (35.2 q/ha^{-1}) and metribuzin (36.1 q ha^{-1}). This might be due to high infestation of weeds in these treatment, which robbed the crop of common resources from initial stages onwards and other herbicides are ineffective to control wild oat. Hence, under stress the crop plants could not grow to their full potential, which ultimately reduced the grain yield to the extent of 53-56 % over weed free. In the present investigation *Avena ludoviciana* dominated the weed flora as broad leaved were chemically controlled in all the plots and severe reduction in wheat yield due to competition from *Avena ludoviciana* has been reported earlier also (Walia *et al*., 2011). Sulfosulfuron, pendimethalin + metribuzin and clodinafop will not be effective as pinoxaden. This was perhaps because all the weed cohorts were not killed by alone PRE and POE herbicides and hence these weeds continued to grow with the crop plants competing with them for the natural resources and thus resulting in poor crop growth in terms of lower dry weight, lesser number of effective tillers, grains per spike and shriveled grains and finally lower grain yields. Similar findings have been reported by Anisha (2014) and Singh *et al*. (2012).

Biological yield represents the total biomass produced by the crop during its growth period. Straw yield indicates the vegetative growth of crop which influences grain yield to a great extent. Both straw yield and biological yield were affected by various treatments in a similar manner as that of grain yield with the highest straw and biological yield being produced in weed free and pinoxaden @ 50 g ha^{-1}, followed by clodinafop 60 g ha^{-1}. This was because of effective control of weeds which provided a favorable environment for the crop to flourish and accumulate more dry weight and hence more straw and biological yield. Other PRE and POE herbicides were inferior to pinoxaden. Weedy treatment recorded least straw and biological yields (52.8 and 84.1 q ha^{-1} respectively) due to suppression of crop by weeds and hence less dry weight accumulation by the crop. These results are in close conformity with Singh *et al*., 2010; Vyavahare and Bhilare, 2015 and Andres *et al*., 2018.

The production and translocation of photosynthates depends upon mineral nutrition supplied. Nutrient supply is one of the most important factors that determine growth of crops. Among all the wild oat management treatments, weed free (135.4, 25.2 and 209.7 kg ha^{-1}, respectively) and application of pinoxaden @ 50 g ha^{-1} (133.7, 24.8 and 206.3 kg ha^{-1}) recorded significantly higher NPK uptake by wheat compared to all other treatments, but were statistically at par with each other. Significantly lower NPK uptake by wheat was obtained in weedy check (69.6, 12.2 and 104.9 kg ha,$^{-1}$ respectively). This is due to better crop establishment in weed free and pinoxaden treated plots were crop growth was superior over all other treatments, this facilitates crop to uptake more nutrients from the soil hence the left out nutrients after harvest was low in weed free and pinoxaden compared to weedy plots. The results are in agreement with the earlier findings of Patro and Ray. (2016) and Sharma *et al*. (2016).

5.7 Effect of wild oat management treatments on density and WCE of wild oat

The influence of different wild oat management treatments on *A. ludoviciana* was studied in terms of visual control of *A. ludoviciana*, density and dry weight accumulation. The weed control efficiency for different weed control treatments were also worked out.

Visual control (per cent) of *A. ludoviciana* was significantly affected by different herbicide treatments (Table 4.42) which was visually assessed that pinoxaden and clodinafop treatments had significant advantage over pendimethalin, metribuzin and pendimethalin + metribuzin in controlling *A.ludoviciana*. Weedy plots had significantly lowest visual control of *A. ludoviciana*. Besides weedy plots, PRE pendimethalin, and POE metribuzin was the least effective herbicide treatments and recorded poor control of *A. ludoviciana* at all the evaluation stages during both the seasons. Lack of mortality of *A. ludoviciana* plants in pendimethalin, metribuzin, pendimethalin + metribuzin and sulfosulfuron could be attributed to the unavailability of lethal dose of herbicide to weeds to cause mortality and lesser effective mode of action against *A. ludoviciana*. Yadav *et al*. (2016) also reported consistently ineffective control of *A. ludoviciana* with PRE pendimethalin 1500 g ha^{-1} and indicated that the sequential application of pendimethalin with post-emergence herbicides could improve weed control when post-emergence herbicides have slightly poor efficacy. Pinoxaden as post emergence application @ 50 g ha^{-1} was the most effective treatment and provided $\geq$ 95 % control of *A.ludoviciana* at all the stages of crop growth. Increasing the dose of pendimethalin significantly improved *A. ludoviciana* control and PRE pendimethalin + metribuzin 1500 g ha^{-1} gave control of *A. ludoviciana* similar to alone POE herbicides, however, these treatments were less effective compared to pinoxaden and clodinafop treatments.

Weed population though does not reflect the true magnitude of weed competition, as it does indicate the extent of pressure exerted by weeds over an area. However, dry matter accumulation by weeds indicates to a great extent, the level of competitive stress the weeds impose on crop plants. All the herbicide treatments significantly reduced the density and dry weight of *A. ludoviciana* compared to weedy plots (Table 4.19 to 4.23). The variation recorded among herbicide treatments was significant with regard to wild oat density and dry weight. The density of *A. ludoviciana* was significantly reduced with pinoxaden @ 50 g ha^{-1} (4 m^{-2}) when compared with weedy check (109 m^{-2}). Clodinafop is although better among other treatments, had higher values for density and dry weight of wild oat when compared with pinoxaden @ 50 g ha^{-1}. Other herbicide treatments like sulfosulfuron and pendimethalin + metribuzin as mixture reduced efficacy against *A. ludoviciana* compared with pinoxaden and clodinafop. This recorded variation in weed control with different POE herbicides could be due to variable mortality pattern observed in *A. ludoviciana* population. The practice of pendimethalin as PRE application and metribuzin as POE application were least effective and recorded highest density and dry weight of *A. ludoviciana* at all the stages followed by weedy. This is perhaps due to no control of first cohorts of weeds and later emerging weeds which dominated plots. Shoeran *et al*. (2013) and Bhagat *et al.* (2017) also found pinoxaden as very effective herbicide against grassy weeds. *P. minor* and *A. ludoviciana* populations have been reported to have high levels of heterogeneity which could be responsible for variable efficacy of different herbicides at (Singh *et al*., 2004). The reduced control of *A. ludoviciana* in the present investigation with herbicide treatments having sulfosulfuron and clodinafop might be due to this phenomenon to these herbicides in *A.ludoviciana* population studied in the field (Kumar *et al*. (2013) and Chhokar *et al.* (2013).

WCE was directly dependent on weed density and weed dry weight hence the results were same with density. WCE is an important index to evaluate the performance of different weed control treatments. WCE represents per cent decrease in density of weeds in treated plots as compared to weedy plots. The weed free plots with highest WCE were followed by plots having pinoxaden @ 50 g ha^{-1} (96.2 %) and clodinafop @ 60 g ha^{-1} (86 %) due to effective control of weeds (Table. 4.23 to 4.24). Besides weedy check, lowest WCE was recorded in plots treated with PRE pendimethalin @ 1.5 kg ha^{-1}(25 %) and metribuzin 175 g ha^{-1}(36 %) followed by POE pendimethalin + metribuzin 1.5 kg ha^{-1}(52 %) and sulfosulfuron 25 g ha^{-1} (60 %). Similar findings were reported by Jain *et al.* (2016) and Shyam *et al.* (2016).

5.8 Effect of fertilizer levels and wild oat management treatments on economics of wheat

Economics is the main parameter which finally decides the adoption levels at farming situations of any newly introduced technology by the farmers. It should be technically and economically viable. Therefore, the economic analysis of the results is very important.

Higher net returns were realized due to the application of 100 % RDF (Rs. 45,782 ha^{-1}). Higher net returns were due to the higher gross returns (Rs. 1.02,690 ha^{-1}). Higher gross returns and net returns were mainly because of the higher yield of the crop (44.7 q ha^{-1}). The higher net returns and gross returns also gave higher B:C ratio (1.80). 120 % RDF showed lower value in the net returns (Rs.34,196 ha^{-1}) mainly because of the low yields (40.2 q ha^{-1}) and gross returns (Rs. 92, 520 ha^{-1}) and also higher cost of cultivation of the crop in 120 % RDF (Rs. 58, 324 ha^{-1}) (Table 4.38 and 4.39).These are result is also in accordance with findings of Harry and James, (2015) and James *et al.*, (2016) for fertilizer levels.

The weedy check had lower B:C (0.52) than weed free and pinoxaden @ 50 g ha^{-1} (2.03 and 2.18),the main reason for this was the yield levels. Higher yield was noticed in the weed free and pinoxaden @ 50 g ha^{-1} (55.3 and 54.8 q ha^{-1}) than weedy check (31.3 q ha^{-1}). Pendimethalin (1.5 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} recorded lowest B:C (1.43 and 1.51, respectively) among the rest of treatments, however main reason for lower B:C was the cost of cultivation (Rs. 57,479 and Rs. 55,543) and poor yield levels, because of cost of herbicide as well as the amount of herbicide was high in both the treatments and poor WCE by was also recorded. The above results are similar to earlier findings by Dev *et al.* (2014) and Ahmedvand *et al.* (2016).

5.9 Effect of fertilizer levels on wild oat in pot studies

Nutrient management is the key approach in improving quality and productivity of wheat. Therefore, optimum use of nutrients throughout the crop period is of vital importance to exploit the production potential of crop. Weeds have naturally good competitive ability, consume more water and nutrients as compared to crop plants and therefore weed management plays a vital role in boosting wheat production. Fertilization may enhance the weed population as well as growth; weeds may reduce the nutrient use efficiency by crop, particularly during the critical period of crop weed competition.

Nutrients favour growth of plants whether is a weed or a crop, it enhances germination percent because of higher availability of nutrients to seeds which emerge out of the soil surface. Martin and field, (2014) stated that fertilization improved the emergence percentage of wild oat. With the application of 120 % RDF the emergence percent of wild oat in pot studies increased to 10.5 % (Table. 4.40) as compared to RDF and helped to maintain better wild oat establishment in 120 % RDF. With better establishment of wild oat, 120 % RDF has increased plat height *i.e.* 44.3, 65.6, 61.5 and 62.4 at 60, 90, 120 DAS and at harvest of wild oat over RDF, respectively. When plant height was more, the number of leaves per plant will automatically increase because of more number of internodes in wild oat (Mohammadi *et al.,* 2012). Availability of nutrients in abundance favors higher number of tiller production in wild oat (Jafar and abdollah, 2015). Higher number of tillers per plant and higher leaves per tiller in wild oat will contribute to the higher dry matter accumulation by wild oat (Ponce 2016). Wild oat dry weight was significantly higher at harvest in 120 % RDF than RDF alone (Table 4.44). The results were in line with the findings of Telavat *et al.* (2010). The per cent increase in wild oat dry weight at harvest was calculated and per cent increase in dry weight of wild oat was significantly high with 120 % RDF over RDF *i.e.* 55.55 % more than RDF. Higher dry weight of wild oat indirectly reflect poor WCE with 120 % RDF (51.05 %) over RDF (57.66 %) Similar findings have been reported by Anderson. (2003). Significantly lower WCE and visual control was noticed in 120 % RDF, which might be due to vigorous growth of wild oat at abundant nutrient level, better availability of nutrients and well-established wild oat plants, delay panicle emergence and flowering in 120 % RDF (75.3 and 79.7 DAS) as compared to RDF (55.5 and 59.1 DAS). Reproductive characters of wild oat were influenced by the application of 120 % RDF. Significantly higher panicle length (19.86 cm), grains per panicle (45.60) and test weight (16.80 g) were recorded with 120 % RDF, whereas significantly lower values were recorded over RDF (10.83 cm, 31.43 and 10.57 g respectively). The higher length of panicle was the result of higher number of vigorous tillers and longer panicles end up with more number of seeds and higher crop vigour also improved the test weight of the seeds. These results are also in accordance with findings of Telavat *et al.*, 2010.

5.10 Effect of wild oat management treatments on wild oat in pot studies

Mortality (per cent) of *A. ludoviciana* was significantly affected by different herbicidal treatments (Table 4.43). Significantly higher mortality % was apparent in pendimethalin + metribuzin @ 1.5 kg ha^{-1}(89.1 and 87.9) and pinoxaden @ 50 g ha^{-1} (81.2 and 82.3) followed by clodinafop @ 60 g ha^{-1} (70.9 and 71.0 %). Pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} were least effective and recorded poor control of *A. ludoviciana* at 45 and 60 DAS during both the seasons. Lack of mortality of *A. ludoviciana* plants in pendimethalin @ 1.5 kg ha^{-1}, metribuzin 175 g ha^{-1}and sulfosulfuron 25 g ha^{-1}could be attributed to the lower availability of lethal dose of herbicide to weeds to cause satisfactory mortality and different mode of action. Poor mortality resulted in significantly higher wild oat height in pendimethalin @ 1.5 kg ha^{-1} (53.1, 75.4, 95.6 and 99.5 cm, respectively) followed by metribuzin @ 175 g ha^{-1} (50.3, 71.9, 95.6 and 99.5 cm, respectively). When compared with pendimethalin + metribuzin 1.5 kg ha^{-1} and application of pinoxaden @ 50 g ha^{-1} least plant height and highest mortality of wild oat was recorded. Control treatment showed highest plant height at all the growth stages (70.9, 103.9, 123.9 and 128 cm, at 60, 90, 120 and at harvest, respectively) when compared with rest of the herbicides. Plant height is an useful and important index of plant growth to provide an idea about dry matter production. With higher plant height the plants will have more number of leaves per plant, hence there will be more accumulation of photosynthates ultimately leading to higher number of tillers and higher dry matter (125.2 g) followed by pendimethalin @ 1.5 kg ha^{-1}(60 g) and metribuzin @ 175 g ha^{-1} (50.3 g) compared to rest of the herbicide treatments. Pinoxaden @ 50 g ha^{-1} and pendimethalin + metribuzin (1.5 kg ha^{-1}) resulted in lowest dry weight accumulation by wild oat in pots *i.e* 5.8 g and 3.4 g, respectively which was too low when compared with control and pendimethalin @ 1.5 kg ha^{-1}.

WCE represents per cent decrease in dry weight of weeds in treated plots as compared to control plots. Pendimethalin + metribuzin @ 1.5 kg ha^{-1} (97.6 %) and pinoxaden @ 50 g ha^{-1} (95.4 %) registered the highest WCE followed by clodinafop @ 60 g ha^{-1} (79.3 %) due to effective control (Table 4.44). Besides control, lower WCE was recorded in pots treated with pendimethalin @ 1.5 kg ha^{-1} (52.2 %), metribuzin 175 g ha^{-1} (60.2 %) and sulfosulfuron 25 g ha^{-1} (58.6 %). These results are in conformity with the findings of Telavat *et al.* (2010) and Singh (2014).

Control and pendimethalin @ 1.5 kg ha^{-1} recorded significantly higher wild oat reproductive parameters when compared with rest of the herbicidal treatments *viz.,* panicle length (25.1 and 21.8 cm), seeds per panicle (61.1 and 57.3) and test weight (22.7 and 19.4 g) over pendimethalin + metribuzin (@ 1.5 kg ha^{-1}) and pinoxaden @ 50 g ha^{-1}, (Tables 4.45 and 4.46). Better growth made wild oat more tolerant and less susceptible to herbicide treatments. Better growth was observed in rest of the treatments except pinoxaden @ 50 g $ha^{-1}$and pendimethalin + metribuzin (@ 1.5 kg ha^{-1}), because these two herbicides controlled wild oat in very effective manner followed by clodinafop @ 60 g ha^{-1}. These results are in conformity with the findings of Telavat *et al.* (2010) and Singh, (2014). *A.ludoviciana* population has been reported to have high levels of heterogeneity which could be responsible for variable efficacy of different herbicides. The reduced control of *Avena ludoviciana* in the present investigation with herbicide treatments having sulfosulfuron 25 g ha^{-1} and clodinafop 60 g ha^{-1} might be due to this factor in *A.ludoviciana* population studied in the field (Sidhu *et al.,* 2014).

CHAPTER-VI

SUMMARY AND CONCLUSIONS

Agronomic investigation on **"Effect of fertilizer levels and herbicides on wild oat management in wheat"** were carried out during *rabi* seasons of 2015-16 and 2016-17. The field experiment was conducted at Weed Control Research area and the pot experiment were conducted in the screen house of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana).

- To study the effect of fertilizer levels and herbicides on growth, yield and nutrient uptake by wheat.
- To study the effect of fertilizer levels and herbicides on wild oat management.
- To work out the economics of different treatments.

The study compressed two experiments, the field experiment and the screen house experiment. In field study, there were 24 treatments and 3 replications with three fertilizer levels and eight wild oat management treatments as main and sub plot treatments respectively in split plot design. Three "fertilizer levels" were ; RDF (F_1), 110 % RDF (F_2) and 120 % RDF (F_3) eight "wild oat management treatments" were; Clodinafop @ 60 g ha^{-1} (W_1), Sulfosulfuron @ 25 g ha^{-1} (W_2), Pinoxaden @ 50 g ha^{-1} (W_3), Metribuzin @ 175 g ha^{-1} (W_4), Pendimethalin @ 1.5 kg ha^{-1} (W_5), Pendimethalin + metribuzin @ 1.5 kg ha^{-1} (W_6), Weed free (W_7) and Weedy check (W_8) here W_5 and W_6 were applied at Pre-emergence while all other herbicides were applied at post emergence. Different growth and yield parameters were recorded at different stages of crop growth for both wheat and wild oat. Nutrient uptake (N, P and K) by crop as well as wild oat and soil nutrient status (N, P, K, kg ha^{-1}) after harvest of the crop was analyzed. Economic analysis was carried out to know the profitability of wheat cultivation under different nutrient and herbicide management systems. Second experiment was carried out in screen house with 3 replications and 21 treatment combinations in Factorial CRD. In screen house weed free (W_7) treatment was excluded in pot studies, only wild oat growth and yield parameters were recorded at different stages of wild oat.

6.1 Effect of fertilizer levels on wild oat management in wheat

Significantly taller plants were obtained with 120 % RDF *i.e.* (39.5, 76.4, 82.8 and 84.4 cm, at 60, 90, 120 DAS and at harvest, respectively) as compared to RDF (36.4, 71.9, 78.2 and 79.6 cm, at 60, 90, 120 DAS and at harvest respectively). Leaf area index was significantly higher with the application of RDF (4.1, 5.93 and 3.57 at 60, 90 and 120 DAS, respectively) when compared with 120 % RDF (3.8, 5.4 and 3.2 at 60, 90 and 120 DAS, respectively).

Significantly higher number of tillers with the application of RDF when compared with 120 % RDF. However, RDF was at par with 110 % RDF. The reduction in tiller number with the application of higher dose of fertilizer *i.e.* 120 % RDF was to the tune of 8.3, 8.9, 6.9 and 7.2 percent at 60, 90, 120 DAS and at maturity. Dry matter production of the wheat with RDF (52.4, 148.3, 199.7 and 227.4 g^{-1}, respectively) was similar to the application of 110 % RDF (51.7, 147.2, 198.9 and 226.5 g^{-1}, respectively) but higher than that with the application of 120 % RDF. RDF accumulated 7.6, 4.8, 4.1 and 2.8 per cent higher dry matter as compared to 120 % RDF at 60, 90, 120 DAS and at maturity, respectively.

Significantly higher wild oat density was recorded with 120 % RDF (55.2, 54.0, 56.3 and 51.9 at 60, 90, 120 DAS and at harvest, respectively) as compared to RDF (42.4, 40.1, 40.9 and 39.8 at 60, 90, 120 DAS and at harvest, respectively). However, RDF was statistically at par with 110 % RDF. With the increase in fertilizer dose from RDF to 120 % RDF there was significant increase in wild oat dry matter. Though 110 % RDF resulted in significantly lower dry matter than 120 % RDF but it did not differ significantly with RDF beyond 60 DAS. The maximum weed control efficiency (%) was recorded in RDF , which was at par with 110 % RDF. Application of 120 % RDF resulted in significantly lower WCE as compared to RDF and 110 % RDF.

Application of RDF recorded significantly lesser panicle length, seeds per panicle and test weight (25.2 cm, 59.3 and 23.6 g, respectively) compared to 120 % RDF (26.9 cm, 61.8 and 24.8 g, respectively), but RDF was at par with 110 % RDF (25.5 cm, 59.7 and 23.7 g, respectively).

The highest grain and straw yield (44.72 and 67.63 q ha^{-1}) were recorded in RDF which was statistically at par with the application of 110 % RDF (43.53 and 66.53 q ha^{-1}). But significantly higher than application of 120 % RDF (40.22 and 61.24 q ha^{-1}). RDF produced 2.73 and 11.18 % higher wheat grain yield as compared with 110 % and 120 % RDF

The highest N, P and K uptake by wheat crop (103.3, 18.7 and 155.3 kg ha^{-1}) obtained with the application of RDF were at par with the application of 110 % RDF (100.6, 18.3 and 152.2 kg ha^{-1}). But significantly higher than that with the application of 120 % RDF.

Available N, P and K after harvest of crop in soil were significantly higher with the application of 120 % RDF (202.1, 28.8 and 203.4 kg ha^{-1}, respectively) when compared with the application of RDF (166.1, 16.1 and 185.1 kg ha^{-1}, respectively). RDF was at par with the application of 110 % RDF. Significantly higher N, P and K uptake by wild oat was obtained with 120 % RDF (12.5, 3.8 and 29.5 kg ha^{-1}) when compared with RDF (7.5, 2.4 and 20.7 kg ha^{-1}) which was at par with the application of 110 % RDF (8.2, 2.5 and 22.2 kg ha^{-1}).

6.2 Effect of herbicides on wild oat management in wheat

Weed free and pinoxaden @ 50 g ha^{-1} resulted in significantly higher plant height (99.9 and 99.7 cm), number of tillers (85.1 and 85 per m.r.l), LAI (4.1 and 4.02), dry weight (247.9 and 247.2 g) and PAR (86.7 and 85.3) as compared to weedy check (plant height 66.3 cm, number of tillers 57.1 per mrl, LAI 2.82, dry matter accumulation 202.6 g and PAR 70.8 at all the growth stages and at harvest. Pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} resulted in poor growth when compared with the rest of the herbicide based wild oat management treatments. Application of clodinafop 60 g ha^{-1} recorded significantly higher growth parameters *viz.*, plant height (88.6 cm), number of tillers (76.8 per m.r.l), LAI (3.6) and PAR (74.8) when compared with sulfosulfuron @ 25 g ha^{-1}.

Application of pinoxaden @ 50 g ha^{-1} (4 No m^{-2}) recorded significantly lower wild oat density as compared to rest of the wild oat management treatments. Significantly higher wild oat density was recorded in weedy check (109 No. m^{-2}) followed by pendimethalin @ 1.5 kg ha^{-1} (76.5 No. m^{-2}) and metribuzin @ 175 g ha^{-1} (65.6 No m^{-2}) at harvest. The higher wild oat per metre square resulted in higher dry weight of wild oat per metre square. Weedy check, pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} recorded 23.8, 17.3, 14.9 times more wild oat dry weight as compared to pinoxaden @ 50 g ha^{-1} (13.2 g m^{-2}). However, clodinafop @ 60 g ha^{-1} recorded significantly lower wild oat dry weight per meter square (43 g m^{-2}) when compared with sulfosulfuron @ 25 g ha^{-1}, both this resulted in significantly higher wild oat dry weight than the pinoxaden @ 50 g ha^{-1}.

The weed free plots with highest WCE were followed by plots having treatment with pinoxaden @ 50 g ha^{-1} (96.2 %) and clodinafop @ 60 g ha^{-1} (86 %) due to effective control of weeds. Besides weedy check, lower WCE was recorded in plots treated with pendimethalin @ 1.5 kg ha^{-1} (25 %) and metribuzin 175 g ha^{-1} (36 %) followed by pendimethalin + metribuzin 1.5 kg ha^{-1} (52 %) and sulfosulfuron 25 g ha^{-1} (60 %).

Significantly higher number of effective tillers per mrl was recorded in weed free and pinoxaden @ 50 g ha^{-1} plots (81.6 and 81.2, respectively) when compared with weedy and rest of the treatments. Weed free and pinoxaden @ 50 g ha^{-1} produced significantly higher dry matter production of wheat compared to rest of the treatments, though these were statistically at par with each other at 60, 90, 120 DAS and at harvest. Significantly lower dry matter production of the wheat was recorded in weedy check (38.4, 114.8, 178.8 and 202.7 g at 60, 90, 120 DAS and at maturity)

Significantly higher panicle length, seeds panicle^{-1} and test weight of wild oat was recorded in weedy check (27.5 cm, 62.7 and 25.4 g, respectively) followed by pendimethalin @ 1.5 kg ha^{-1} (26.99 cm, 61.4 and 24.8 g, respectively) and metribuzin @ 175 g ha^{-1} (26.7

cm, 61.2 and 24.7 g, respectively). Pendimethalin + metribuzin (1.5 kg ha^{-1}) recorded higher panicle length, seeds $panicle^{-1}$ and test weight (26.1 cm, 60.4 and 24.3 g, respectively) when compared with sulfosulfuron @ 25 g ha^{-1} (25.5 cm, 60.3 and 23.8 g, respectively), whereas, clodinafop @ 60 g ha^{-1} recorded significantly lower attributes (24.5 cm, 59.3 and 23.3 g, respectively) when compared with sulfosulfuron @ 25 g ha^{-1}, but was significantly higher than the pinoxaden @ 50 g ha^{-1}. Application of pinoxaden @ 50 g ha^{-1} (23.7 cm, 57.6 and 21.91 g, respectively) recorded lower values of yield attributes as compared to rest of the treatments. The interaction effects of wild oat management treatments and fertilizer levels found to be non-significant in respect of the yield attributes.

Weed free (55.3 and 79.07 q ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (54.8 and 78.61 q ha^{-1}) being at par with each other produced significantly higher grain and straw yield as compared to rest of the treatments. Clodinafop @ 60 g ha^{-1} recorded significantly higher grain and straw yield (46.81 and 69.75 q ha^{-1}) as compared with sulfosulfuron @ 25 g ha^{-1} (42.95 and 66.03 q ha^{-1}) though it was significantly lower than the pinoxaden @ 50 g ha^{-1}. Pendimethalin @ 1.5 kg ha^{-1} (35.24 and 56.70 q ha^{-1}) and metribuzin @ 175 g ha^{-1} (36.11 and 57.06 q ha^{-1}) produced statistically similar grain yield.

Weed free (135.4, 25.2 and 209.7 kg ha^{-1}) and pinoxaden @ 50 g ha^{-1} (133.8, 24.9 and 206.1 kg ha^{-1}) being at par with each other recorded significantly higher N, P and K uptake compared to rest of the wild oat management treatments during both the years as well as in pooled data. Significantly lower uptake of nutrients by wheat crop was recorded in weedy check (69.6, 12.2 and 104.9 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (77.7, 13.7 and 115.6 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (79.5, 14.1and 117.5 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly higher N, P and K uptake by wheat crop (109.7, 19.1 and 160.7 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (95.5, 17.3 and 145.5 kg ha^{-1}) but was significantly lower than the pinoxaden @ 50 g ha^{-1}.

Weed free (0.4, 0.1 and 1.1 kg ha^{-1}) and application of pinoxaden @ 50 g ha^{-1} (0.7, 0.2 and 1.8 kg ha^{-1}) recorded significantly lower N, P and K uptake by wild oat compared to rest of the treatments, but were statistically at par with each other. Significantly higher nitrogen, phosphorus and potassium uptake by wild oat was documented in weedy check (24.6, 7.6 and 61.5 kg ha^{-1}) followed by pendimethalin @ 1.5 kg ha^{-1} (16.2, 5.2 and 42.1 kg ha^{-1}) and metribuzin @ 175 g ha^{-1} (13.9, 4.6 and 35.8 kg ha^{-1}). Clodinafop @ 60 g ha^{-1} recorded significantly lower N, P and K uptake by wild oat (2.7, 0.7 and 7.2 kg ha^{-1}) when compared with sulfosulfuron @ 25 g ha^{-1} (7.4, 2.1 and 19.5 kg ha^{-1}) but was significantly higher than the pinoxaden.

Among the fertilizer levels higher B:C was recorded with RDF (1.78 Rs) over 120 % RDF (1.56 Rs). Whereas among wild oat management practices superior B:C was observed in application of pinoxaden @ 50 g ha^{-1} (2.18 Rs) followed by weed free (2.03 Rs) and clodinafop (1.91 Rs).

Application of 120 % RDF with weed free situation resulted in significantly higher growth and yield parameters as well as nutrient uptake of wheat, compared to all other treatment combinations except F_3W_3, F_2W_7, F_1W_7, F_2W_3 and F_1W_3 which were at par with each other. Weed free and pinoxaden @ 50 g ha^{-1} produced statistically similar type of growth and yield parameters at all the fertilizer levels but numerically higher in 120 % RDF. Whereas, it reverse in case of rest of the treatment combination.

6.3 Effect of fertilizer levels and herbicides on wild oat management in screen house

Significantly lower wild oat height was recorded with the application of recommended dose of fertilizer (28.6, 39.1, 46.6 and 48.3 cm, respectively) when compared with 120 % RDF (41.2, 60.1, 74.9 and 77.2 cm, respectively). Application of 110 % recommended dose of fertilizer (30.4, 43.6, 55.3 and 57.7 cm, respectively) was at par with RDF in all the growth stages.

Wild oat dry weight at harvest was significantly higher with the application of 120 % RDF (54.6 g) when compared with RDF (35.1 g) and 110 % RDF (41.2 g). Similar results were observed in WCE. The WCE with the application of RDF (57.66 %) was at par with the application of 110 % RDF (55.88 %) but significantly higher than application of 120 % RDF (51.05 %). Higher dry weight and lesser WCE resulted in significantly lower wild oat mortality with the application of 120 % RDF (54.04 and 53.22 %) as compared to application of RDF (61.18 and 62.16 %) and 110 % RDF (59.67 and 59.92 %) at both 60 and 90 DAS.

Significantly longer panicle, seeds per panicle and test weight were observed with the application of 120 % RDF (19.8 cm, 45.6 and 16.8 g, respectively) when compared with RDF (10.8 cm, 31.4 and 10.5 g, respectively) which was at par with the application of 110 % RDF (12.88 cm, 35.7 and 12.7 g, respectively).

CONCLUSION:

Application of recommended dose of fertilizer increased by grain yield 11.18 % and straw yield by 10.43 % over 120 % RDF. All the growth parameters *i.e.* (leaf area index, number of tillers mrl, dry matter) yield parameters (Grains spike^{-1}, spikelets spike^{-1}, spike length, test weight) and nutrient uptake in RDF ware significantly higher over 120 % RDF. Increase in fertilizer dosage from RDF to 120 % RDF increased the density of wild oat and decreased the WCE.

Among the wild oat management practices, weed free conditions and application of pinoxaden @ 50 g ha^{-1} produced significantly higher grain and straw yield compared to all other treatments. Whereas, highest B:C rates was observed with application of pinoxaden @ 50 g ha^{-1} (2.18 Rs) followed by weed free (2.03 Rs) and clodinafop (1.91 Rs).

In screen house conditions, application of higher dose of nutrients increased the dry weight of wild oat and decreases the WCE. Application pendimethalin + metribuzin @ 1.5 kg ha^{-1} followed by pinoxaden @ 50 g ha^{-1} provided better control of wild oat than any other treatment

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Appendix-I: Mean weekly meteorological data during crop season 2015-16

SMW	Maximum temperature (^oC)	Minimum temperature (^oC)	Relative humidity (%)		Average wind speed (Km hr^{-1})	Rainfall (mm)	Bright Sunshine hour
			Morning	Evening			
45	28.3	15.3	94	41	2.4	0.0	2.8
46	29.1	12.8	86	36	2.7	0.0	7.5
47	27.7	9.0	91	36	1.2	0.0	7.7
48	25.3	9.5	95	50	2.5	0.0	4.2
49	25.5	8.8	97	51	2.2	0.0	5.5
50	21.4	7.1	95	45	3.4	0.0	5.2
51	20.6	3.5	98	44	2.0	0.0	6.2
52	21.3	4.0	93	42	2.0	0.0	6.4
1	22.7	6.4	97	58	2.1	0.0	4.9
2	22.4	8.4	95	59	2.7	0.0	4.9
3	15.3	6.1	90	75	2.9	0.0	2.2
4	16.4	5.5	97	66	3.4	0.0	4.2
5	22.1	7.1	95	53	2.6	0.0	6.2
6	22.9	6.3	91	52	3.1	0.0	6.8
7	21.9	6.2	92	53	3.4	5.3	6.7
8	26.0	10.3	94	45	4.2	0.0	7.2
9	29.0	11.7	91	45	3.6	0.0	8.2
10	28.2	13.5	94	55	4.1	14.7	8.3
11	28.3	14.0	92	54	5.1	8.7	5.9
12	31.5	13.4	83	43	5.6	1.8	9.3

SMW, standard meteorological week

Appendix-II: Mean weekly meteorological data during crop season 2016-17

SMW	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)		Average wind speed (Km hr^{-1})	Rainfall (mm)	Bright Sunshine hour
			Morning	Evening			
45	28.3	9.1	91	47	2.2	0.0	7.8
46	26.2	7.4	95	51	1.2	0.0	7.3
47	24.7	9.2	98	54	2.7	0.0	5.8
48	23.7	5.3	98	51	2.0	0.0	7.4
49	21.9	7.7	99	70	3.4	0.0	4.5
50	20.1	9.9	100	80	5.0	5.8	2.9
51	17.6	3.2	99	60	2.4	0.0	6.0
52	16.9	3.9	96	66	3.2	0.8	4.3
1	20.0	10.4	99	81	4.1	34.6	3.1
2	20.6	7.8	98	64	2.2	0.0	5.6
3	21.6	7.0	93	53	3.7	0.0	6.9
4	24.5	7.4	90	45	1.9	0.0	7.8
5	26.8	9.1	90	37	2.6	0.0	8.4
6	26.9	8.3	92	37	2.8	0.0	8.6
7	25.6	9.7	89	45	4.8	7.5	7.6
8	25.1	7.4	90	40	2.7	0.0	8.3
9	32.0	13.6	90	34	2.8	0.0	9.2
10	36.3	16.7	85	30	2.8	0.0	9.6
11	35.7	17.5	68	27	7.2	0.0	6.9
12	37.2	14.0	59	16	3.2	0.0	10.3

SMW, standard meteorological week

Appendix- III: Cost of cultivation (Rs per ha^{-1}) of different treatments

Sr. No.	Operations	Wheat (per ha^{-1})	
		2015-2016	2016-2017
1	Preparatory tillage	1202	1000
2	Pre sowing irrigation	2450	1595
3	Ridging	85	150
4	Sowing	2100	1989
5	Seed cost	2875	2898
6	Seed treatment	12	15
7	Fertilizer	6155	6155
8	Irrigation	1854	1854
9	Sowing and fertilizer application	625	625
10	Weeding	4320	5460
11	Plant protection	525	525
12	Harvesting	7435	7435
13	Threshing	4687	4879
14	Interest on working capital	524	556
15	Management charges	1218	1279
16	Transportation	468	480

Source: Department of Agricultural Economics, college of Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar

Appendix- IV: Cost of herbicides and nutrients

Sr. No.	Herbicides		Cost (Rs)	Cost (Rs ha^{-1})
1	Pinoxaden	(400 ml)	Rs 740	Rs. 1850
2	Metribuzin	(100 g)	Rs 199	Rs. 500
3	Pendimethalin	(1 lit)	Rs 477	Rs. 2385
4	Clodinafop	(160 g)	Rs 410	Rs. 1025
5	Sulfosulfuron	(16 g)	Rs 510	Rs. 1020
6	Pendimethalin + metribuzin	(400 ml)	Rs 740	Rs. 2882
7	Carfentrazone	(100 g)	Rs 199	Rs. 530
	Nutrients		**Cost (Rs ha^{-1})**	
8	Nitrogen	(Rs. 12 kg)	Rs. 1800	
9	Phosphorus	(Rs. 46 kg)	Rs. 2760	
10	Potassium	(Rs. 17 kg)	Rs. 1020	
11	Zink sulphate	(Rs. 23 kg)	Rs. 575	

ABSTRACT

Title of thesis	:	Effect of fertilizer levels and herbicides on wild oat management in wheat
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Admission No.		**2014A09D**
Title of degree	:	Doctor of Philosophy in Agronomy
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Degree awarding University	:	CCS Haryana Agricultural University, Hisar-125 004, Haryana (India)
Year of award of degree	:	2018
Major subject	:	Agronomy
Total pages in thesis	:	136 + i-xii + Appendices
Total words in the abstract	:	565

Key words: Recommended dose of fertilizer, Benefit cost ratio, wild oat (*Avena ludoviciana*), herbicides, growth, nutrient uptake, productivity, weed management, economics.

The present investigation entitled, **"Effect of fertilizer levels and herbicides on wild oat management in wheat"** was conducted in field as well as screen house of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana) during *rabi* 2015-16 and 2016-17. In field study there were 24 treatments and 3 replications with 3 fertilizer levels as main plot and 8 wild oat management treatments as sub plot treatments assigned as per split plot design. "fertilizer levels" with 3 levels *i.e.* RDF, 110 % RDF and 120 % RDF and "wild oat management treatments" compressed Clodinafop @ 60 g ha^{-1}, Sulfosulfuron @ 25 g ha^{-1}, Pinoxaden@ 50 g ha^{-1} and weed free conditions, Metribuzin @ 175 g ha^{-1}, Pendimethalin @ 1.5 kg ha^{-1} (PRE), Pendimethalin + metribuzin @ 1.5 kg ha^{-1} (PRE), Weed free and Weedy check. In screen house study 21 treatment combinations, 3 fertilizer doses and 7 wild oat management practices were replicated three times as per Factorial CRD.

Significantly higher mean grain yield (44.7 q ha^{-1}), straw yield (66.7 q ha^{-1}) and B:C (1.80) were recorded in RDF when compared with 120 % RDF (40.22 q ha^{-}1, 61.24 q ha^{-1} and 1.58, respectively). Weed free (55.3 q ha^{-1}, 79.1 q ha^{-1} and 2.03) and pinoxaden @ 50 g ha^{-1} (54.8 q ha^{-1}, 78.6 q ha^{-1} and 2.18) being at par with each other produced higher grain yield, straw yield and B:C, whereas, weedy produced the lowest values. Clodinafop @ 60 g ha^{-1} recorded significantly higher grain yield, straw yield and B:C as compared with sulfosulfuron @ 25 g ha^{-1} though it was significantly lower than the pinoxaden @ 50g ha^{-1}. Pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} produced statistically similar grain yield, straw yield and B:C. With the increase in fertilizer dose from RDF to 120 % RDF there was significant increase in wild oat dry matter .Though 110 % RDF resulted in significantly lower dry matter (120 g m^{-2}) than 120 % RDF (160 g m^{-2}) but it did not differ significantly with RDF (112 g m^{-2}) beyond 60DAS. In wild oat management treatments, weedy check, pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1} recorded 23.8, 17.3, 14.9 times more wild oat dry weight as compared to pinoxaden @ 50 g ha^{-1} (13.2 g m^{2}). However, clodinafop @ 60 g ha^{-1} recorded significantly lower wild oat dry weight (43 g m^{-2}) when compared with sulfosulfuron @ 25 g ha^{-1}, but these were significantly higher than the pinoxaden @ 50 g ha^{-1}. Significantly higher N (103.3 kg ha^{-1}), P (18.7 kg ha^{-1}) and K (155.3 kg ha^{-1}) uptake by wheat crop was recorded with the application of RDF when compared with120 % RDF. Weed free (135.4, 25.2 and 209.7 kg ha^{-1}) and pinoxaden @ 50 g ha^{-1} (133.8, 24.9 and 206.1 kg ha^{-1}) being at par with each other recorded significantly higher N, P and K uptake compared to rest of the wild oat management treatments. Significantly lower uptake of nutrients by wheat crop was recorded in weedy check followed by pendimethalin @ 1.5 kg ha^{-1} and metribuzin @ 175 g ha^{-1}.

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I, **Pavankumar Goudar**, Admn. No. **2014A09D,** undertake that I give copyright of my thesis entitled **“Effect of fertilizer levels and herbicides on wild oat management in wheat”** to CCSHAU, Hisar.

I also undertake that, patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission of the competent authority of CCS HAU, Hisar.

(Pavankumar Goudar)