COMPETITIVE ABILITY OF WHEAT (*Triticum aestivum* L.) AGAINST WILD OATS (*Avena ludoviciana* Dur.) AS INFLUENCED BY DATE OF SOWING, SEED RATE AND SPACING

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
in
AGRONOMY
(Minor Subject : Botany)

By

Ramandeep Singh Sandhu
(L-2005-A-11-M)

Department of Agronomy
College of Agriculture
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA - 141 004

2007

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CERTIFICATE – I

This is to certify that the thesis entitled, **"Competitive ability of wheat (*Triticum aestivum* L.) against wild oats (*Avena ludoviciana* Dur.) as influenced by date of sowing, seed rate and spacing"** submitted for the degree of **M. Sc.** in the subject of **Agronomy** (Minor Subject: **Botany**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ramandeep Singh Sandhu (L-2005-A-11-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

Major Advisor
(Dr. B. S. Gill)
Agronomist
Department of Agronomy,
Punjab Agricultural University
Ludhiana- 141004 (India)

CERTIFICATE-II

This is to certify that the thesis entitled, **"Competitive ability of wheat (*Triticum aestivum* L.) against wild oats (*Avena ludoviciana* Dur.) as influenced by date of sowing, seed rate and spacing"** submitted by **Ramandeep Singh Sandhu (L-2005-A-11-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfilment of the requirements for the degree of **M.Sc.** in the subject of **Agronomy** (Minor Subject: **Botany**) has been approved by the Student's Advisory Committee along with Head of the Department after an oral examination on the same.

19/11/07

Head of the Department
(Dr. Dalip Singh)

19.11.07

Major Advisor
(Dr. B. S. Gill)

Dean, Post-Graduate Studies
Dr. (Mrs.) S.K. Mann

ACKNOWLEDGEMENTS

First of all with great humility, I dedicately accord my sincere gratitude to ***'Akal Purkh Waheguru'*** *for his benign blessing hand and bestowing a creative and healthy environment through out my academic and research period.*

I feel great elation in expressing gratitude to my worthy major advisor ***Dr. B.S.Gill,*** *Agronomist, for his aesiduous scholarly guidance, inerrant encouragement and conductive criticism which enabled me to accomplish the hard task of completing the present study and making the thesis worth of presentation. His overly enthusiasm and integral view on research and his mission for providing 'high-quality work' has made a deep impression on me. I owe him lots of gratitude for having me shown this way of research.*

I would also like to thank the esteemed members of my advisory committee who monitored my work, gave insightful commands on earlier versions of this thesis. ***Dr. Tarlok Singh,*** *Senior Agronomist,* ***Dr. D.S. Gill,*** *Senior Plant Physiologist and Dr.* ***R.K. Mahey,*** *Professor and Head (Dean PGs Nominee) Deptt. of Agronomy.*

I am grateful to ***Dr. R.K. Mahey,*** *Head, Department of Agronomy for prompt solution of problems and timely provision of necessary research facilities.*

Mere words of acknowledgment will never express the sense of regards and indebtedness towards my Dad, ***S. Harinder Singh****, whose support and selfless sacrifices that enabled me to pursue my studies with unfailing zeal and devotion, have brought me upto this stage of career. I pay my sublime obeisance to my esteemed mother,* ***Smt. Lakhvir Kaur*** *and elder sisters,* ***Gagan and Aman****, who were my source of strength and inspiration.*

No words can suffice my feelings of immense gratitude to, ***Amandeep Sidhu*** *for extending his help during my research work. A special word of appreciation is due for the wonderful company of my friends* ***Harsimran, Ajay, Jugpreet, Balraj, Devinder, Pam and Kuldeep*** *who always shared burden of my work, cheered me in the moments of despair and made things much smoother.*

All may not have been mentioned but none is forgotten.

Ramandeep Singh

(RAMANDEEP SINGH SANDHU)

Title of Thesis	:	Competitive ability of wheat (*Triticum aestivum* L.) against wild oats (*Avena ludoviciana* Dur.) as influenced by date of sowing, seed rate and spacing"
Name of the Student and Admission No.	:	Ramandeep Singh Sandhu L-2005-A-11-M
Name and Designation of Major Advisor	:	Dr. B. S. Gill) Agronomist
Major Subject	:	Agronomy
Minor Subject	:	Botany
Degree to be Awarded	:	M.Sc.
Year of Award of Degree	:	2007
Total Pages in Thesis	:	85
Name of the University	:	Punjab Agricultural University, Ludhiana

ABSTRACT

A field experiment was conducted at Punjab Agricultural University, Ludhiana during *Rabi* 2006-2007 to study "Competitive ability of wheat (*Triticum aestivum* L.) against wild oats (*Avena ludoviciana* Dur.) as influenced by date of sowing, seed rate and spacing." Three dates of sowing (November 1, November 15 and November 30) formed the main plot treatments, two seed rates (100kgha^{-1} and 150kg ha^{-1}) and two spacings (15 cm and 22.5 cm) were kept in the sub plots and herbicide treatments comprising clodinafop 60 g ha^{-1} and unweeded check were adjusted in the sub-sub plots. In all there were 24 treatment combinations having three replications. The crop sown on November 1 had higher LAI, thus had more PAR interception, dry matter production and effective tillers. It had more suppressing effect on *Avena ludoviciana* by reducing the dry matter accumulation by 10.4 percent and 16 percent, respectively over November 15 and November 30 sowings and thus resulting in 7.9 percent and 21.6 percent higher grain yield over November 15 and November 30 sown crop. Higher crop density achieved with seed rate of 150 kg ha^{-1} added to the smothering potential of the crop against *Avena ludoviciana* by increasing dry matter production (16.8 percent), number of effective tillers (10 percent), PAR interception by wheat crop which reduced the dry matter production of *Avena ludoviciana* by 27.7 percent, thus resulted in 5 percent higher grain yield of wheat crop compared to recommended seed rate of 100 kg ha^{-1}. Crop sown in narrow rows of 15cm competed well with *Avena ludoviciana* than the crop sown with wider rows of 22.5 cm and reduced the dry matter of *Avena ludoviciana* by 25.9 percent, thereby gave 6 percent gain in yield of wheat crop. The post emergence application of clodinafop 60 g ha^{-1} provided complete kill of the emerged plants of the weed and thus gave 54.48 percent increase in grain yield over unweeded check.

Key words: Wheat, *Avena ludoviciana,* Dates, Seed rate, Spacing, Clodinafop.

Ramandeep Singh
Signature of Student

19.11.07
Signature of Major Advisor

CONTENTS

CHAPTER-1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important cereal crop of Indo-gangetic plains in general and of Punjab in particular. In India, it is the second important food crop being next to rice and occupies 26.6 million hectare with a total production of 69.48 million tones of grains and a productivity of 2.61 tonnes per hectare (Anonymous 2007a). In Punjab, it occupies the distinct position with an area of 3.47 million hectare with production of 14.49 million tonnes and average yield of 4.18 tonnes per hectare (Anonymous 2007b). Weeds compete with the crop for different inputs viz., soil moisture, nutrient, light, space etc. So for attaining economic yields, weeds must be controlled properly by any effective weed control method especially, at critical period of crop weed competition. Weed control is an important factor governing the yield of wheat crop. Introduction of semi- dwarf wheat varieties and intensive cropping system coupled with better irrigation facilities and higher fertilizer application has provided congenial conditions for growth and resulted in higher production of food grains. However, this has also brought along with it the increased problem of weeds. The mixed infestation of *Phalaris* *minor*, *Avena ludoviciana*, *Lolium temulentum* and *Poa annua* in wheat reduced grain yield by 10-50 per cent (Kumar and Singh 1994).

Among the weeds known as wild oats, *Avena sterilis* ssp. *ludoviciana* is the most common and wide spread (Torres 1994). It germinates quickly, establishes a deep and extensive root system and responds dramatically to higher levels of nitrogen (Carlson 1986). The main features contributing to its spread are its similar ecological requirements to that of wheat, earlier shedding of seeds and ability of seeds to remain dormant in soil for several years (Christensen 1996). This weed not only competes with wheat for growth factors (Johri *et al* 1992) but it is also responsible for forceful lodging of the wheat crop due to its weak stem. Wild oats (*Avena ludoviciana* Dur.) is a serious weed of wheat grown on well drained light to medium textured soils where wheat follows maize, groundnut, cotton, fodder, pulse crops.

Chemical weed control i.e. spraying of weedicide is the most effective method to reduce weed infestation. New herbicides like clodinafop, sulfosulfuron and fenoxaprop-p-ethyl provide excellent control of *P. minor* and *Avena ludoviciana* (Banga and Yadav 2004). However, continuous use of herbicides may lead to resistance in weeds (Walkar *et al* 2002, Andrew *et al* 1998), shifting weed flora, environmental pollution, residue of herbicides in soil, persistence in crop produce and biomass. There is a need to tackle the weed problem by devising effective and viable management techniques. Among which, cultural methods i.e. agronomic manipulations can prove quite useful. Some of the agronomic techniques such as crop rotation (Martin and Felton 1993), variable plant density (Kappler *et al* 2002), crop geometry (Sharma and Angiras 1996), manipulation of sowing time (Virk 2001) can be effectively integrated with herbicide to allow the crop weed competition in favour of crops with less load of herbicides per unit area and can help in sustaining agriculture.

Among these, dates of sowing, row spacing and seed rate are important cultural practices which can be an ideal tool of weed management for minimizing the use of costlier herbicides and their bad effects on environment. In every agroclimatic region there is a peak period of germination of seasonal weeds. Crops can be made to escape early crop-weed competition by planting them little earlier or later than their normal planting time (Gupta 1998).

In crop-weed ecosystem, increase in the number of crop plants per unit area greatly facilitates weed suppression by maintaining dominant position over weed through modification in crop structure (Gill 1992). So these cultural practices need to be promoted and more information of these aspects needs to be generated under Punjab conditions. Keeping above facts in view the present study has been planned with following objectives:

1. To assess the smothering potential of wheat against *Avena ludoviciana* as influenced by dates of sowing, seed rate and row spacing.
2. To evaluate the competitive ability of wheat along with clodinafop against *Avena ludoviciana* and its effect on productivity of wheat.

CHAPTER-2

REVIEW OF LITERATURE

Wild oat (*Avena ludoviciana* Dur.) a grassy weed popularly known as jaundhar and jangli javi, is a troublesome weed infesting the wheat crop throughout the state as well as adjoining states. *Avena ludoviciana* in northern India poses serious problem to the cultivation of wheat and efficient utilization of inputs. Depending upon infestation, it may result in considerable reduction in grain yield of wheat. The relevant literature pertaining to different aspects has been reviewed under the following heads:

(a) Crop weed competition

(b) Effect of date of sowing on the competition from wild oats

(c) Effect of seed rate on the competition from wild oats

(d) Effect of spacing on the competition from wild oats

Crop-weed competition

Many factors interact in determining the out come of competition between weeds and crops. Though, weed density is a major factor causing yield reduction in crops, but the amount of yield loss per individual weed plant is variable over a wide range depending on conditions such as time of emergence (day length), soil fertility, proximity and type of neighbours and soil moisture (Norris 1998). The extent of damage varied with the condition of soil, availability of moisture and nutrients, stages of crop-weed competition and intensity of weed flora (Chopra *et al* 1999). Walia *et al* (2001) concluded that wheat yield decreased exponentially with the increase in wild oat density 1 to 10, 15, 20, 25 and 30 plants m^{-2} .Wheat yield loss was between 1.06 to 15.0 per cent upto 3 plants of wild oat m^{-2} and reached upto 30 to 40 per cent at 10 plant m^{-2}. Carlson and Hill (1986) reported that *A. fatua* at a density of 311 plants m^{-2} (the highest tested) reduced wheat yield by 65 per cent as compared with uninfested crop. However, yield losses from *A. fatua* competition were reduced with increasing density of spring wheat.

Kirkland (1993) reported that failure to remove wild oats reduced wheat yield by 28 to 29 per cent at wild oats population of 64 to 188 plants m^{-2} respectively. Wild oats densities of 64 or 188 plants m^{-2} did not reduce wheat yield until the 6 and 7 leaf stage of wild oats, respectively.

According to Wilson *et al* (1990) competitive effects of *A. fatua* were greater at low crop densities. Crop head number reduced proportionally less than crop yield, indicating that competition was affecting other yield components. It was concluded that at average crop densities, low infestation of *A. fatua* are likely to result in cereal yield losses in the region of 1 per cent for each *A. fatua* plant m^{-2}. Wild oat (*Avena ludoviciana* L.) reduced wheat yield by 16 to 46 per cent with an infestation 40 to 60 plants m^{-2} respectively (Balyan and Malik, 1991).

Rooney (1990) observed greater reduction in growth and yield of wheat cv. Avalon when competing with prostrate form of *A. fatua* than with an upright form. The prostrate form was taller than the crop at anthesis. Due to availability of sufficient amount of moisture and nutrients weeds attained competitive advantage and inflict severe losses in wheat yield varying from 10 to 82 per cent depending upon their intensity (Tiwari 1993).

Balyan *et al* (1991) observed that natural infestation of wild Oat at146 to 162 plant m^{-2} reduced wheat grain yield by 17 to 62 per cent depending upon the cultivars grown.

Montazeri (1993) found that wild oat and wild cannary grass infestation of 12 to 30 plants m^{-2} reduced the grain yield of wheat by 18 to 35 and 18 to 46 per cent, respectively. Weeds reduce wheat yield severely from 10.0 to 82.2 per cent depending upon the nature, intensity of weeds and duration for which the weeds compete with crop (Punia *et al* 1993, Tiwari 1993).

The mixed infestation of *Phalaris minor*, *Avena ludoviciana*, *Lolium perenne* and *Poa annua* in wheat reduced the grain yield by 10 to 50 per cent (Kumar and Singh 1994). Walia *et al* (1997) reported that when the density of wild oats increased, wheat yield decreased exponentially. Wheat yield loss was below 1 per cent upto 3 plants of wild oats m^{-2}, reached 2.2 per cent at 5 plants and was 50 to 60 per cent at 100 plants of wild oats m^{-2}. Wheat yield loss can also be related to the dry weight of wild oats. Samra and Dhillon (1993) observed that the competition of weeds in wheat resulted in significant reduction in grain yield of the crop. Yield losses especially from *Phalaris minor* alone are estimated to the tune of 25 to 50 per cent and in very severe infestation, the losses may go up to 80 per cent (Malik *et al* 1996).

Date of sowing

Crops can be made to escape early weed crop competition by planting them little earlier or later than their normal planting time (Gupta 1995). In every agroclimate, there is a peak period of germination of seasonal weeds. After studying the biology of a troublesome weed, the sowing of the crop can be manipulated in such a way that ecological condition for germination of weed seeds are not met due to escape mechanism (Walia 2003). Singh *et al* (1995) reported that winter wild oats emergence and sowing date interaction indicated that winter wild oats emergence in October and early November was lower than in late November or early December. Yaduraju *et al* (1997a) found that the density and biomass of *Phalaris minor* and *Avena ludoviciana* were highest with 15th November planting and decreased there after with each delay in planting upto 1st January with 15 days interval.

Christensen *et al* (1996) reported that late sowing reduced the emergence and survival of broad leaved weed species significantly. The result of field experiments conducted over a number of years at Punjab Agricultural University also showed that wheat crop sown in Nov.-Dec. have more serious problem of grassy weeds, than the broad leaf weeds (Anonymous 1992-93). Field trials conducted in Germany showed that early sowing of wheat having strong influence on *Alopecurus myosuroides* than late sowing could be used as indirect control measure and such contribution to weed control should be practically important in the absence of highly effective direct control measure (Amann *et al* 1992).

The temperature between 17.2 to 28.0°C is favourable for germination of *Avena ludoviciana* and wild oats did not germinate in October while sowing of wild oats in December caused reduction in plant height, length of panicle and number of spikelets per panicle of wild oats, compared to that sown during early November (Singh and Ghosh 1992). Singh *et al* (1995) observed that mortality of winter wild oats increased from 38 to 72 per cent in November 10, November 30 and December 20 sowings, respectively. Mortality of winter wild oats was similar in November 30 and December 20 sowings but higher grain yield was recorded in November 30 sowing. Walsh (1995) in Victoria found that delayed seeding of wheat did not effect wild oat population due to the extended germination pattern of the weed. Yaduraju and Ahuja (1997b) conducted field trials at New Delhi and reported that the density and biomass of both *Phalaris minor* and *Avena ludoviciana* were the highest with November 15 planting and decreased thereafter with each delay in planting and the grain yield of wheat was maximum when planted on November 1st. The 25th October sown crop owing to its more dry matter production caused 26.9 per cent reduction in dry matter accumulation by *Phalaris minor* and hence resulted in 21.6 per cent higher yield over 10th November sown crop (Mahajan and Brar 2001).

Grain yield of early sown crop i.e. October 25 was significantly higher as compared to normal sown crop i.e. November 10. Dry matter accumulation by *P. minor* was significantly less in the crop sown on October 25 compared to crop sown on November 10 (Virk *et al* 2003).

Panwar *et al* (1990) reported maximum population of *Avena ludoviciana* when wheat was sown on 15th November and the population of *Avena ludoviciana* decreased significantly with the delay in sowing dates after 15th November.

Seed rate

Increasing the seed rate of wheat is also an effective agronomic manipulation which may turn the crop weed competition in favour of the crop. In crop weed ecosystem increase in the number of crop plant per unit area greatly facilitate weed suppression by maintaining dominant position over weeds through modification in canopy structure (Gill 1992). In wheat increase in seed rate significantly reduced the weed population and dry weight of weeds at all the stages due to the competition offered by the crop stand for space, nutrient, moisture and solar radiation (Bhan and Kumar 1998). Panwar *et al* (2000) reported that seed at the rate of 175 kg ha^{-1} significantly reduced the population and dry weight of weeds compared with seed at the rate of 100 or 125 kg ha^{-1}. The magnitude of decrease was more in the dry weight than in the population of weeds. A close canopy cover mediated through more tillers allowed the competition in favour of crop at higher seed rate.

Walia *et al* (2001) also found that a high seed rate of 150 kg ha^{-1} suppressed wild oats effectively thus significantly reducing the dry matter accumulation of the weeds. Walia and Brar (2001) at Ludhiana concluded that using higher seed rate of 150 kg ha^{-1} resulted in significant reduction in dry mater accumulation by wild oats (*Avena ludoviciana*) as compared to recommended seed rate of 100 kg ha^{-1}. Total dry matter production by *Avena ludoviciana* and broad leaf weeds was also found to be significantly low in higher plant density treatment as compared to recommended plant density. It may be attributed to more competition by wheat crop on the associated weeds particularly during initial stages.

Bhan (1987) reported significant reduction in dry matter accumulation by weeds by increasing seed rate of wheat from 100 kg ha^{-1} to 150 kg ha^{-1}. Singh *et al* (1996) observed that increasing the seed rate from 100 kg ha^{-1} to 150 kg ha^{-1} significantly reduced weed population and dry weight, which may be due to competition offered by crop plants for space, nutrients, moisture and solar radiation. Highest grain yield was observed with 150 kg ha^{-1} seed rate which may be due to reduced weed competition and increased number of ears m^{-2}. Sodhi and Dhaliwal (1998) at Ludhiana reported an inverse relationship between crop seed rate, wild oat plant height and dry matter accumulation. As seed rate of wheat increased from 100 to 200 kg ha^{-1}, plant height and dry matter accumulation of wild oats (*Avena ludoviciana*) decreased significantly. Grain yield of wheat was significantly highest (46.4 q ha^{-1}) at a seed rate of 200 kg ha^{-1}. Yaduraju and Ahuja (1997) observed lower population and weight of *Avena Ludoviciana* at higher seed rate of 150 kg ha^{-1} as compared to 100 kg ha^{-1}. Grain yield was not significantly affected due to variable seed rates.

In another study, Korres and Williams (1997) observed that seed rate significantly affected weed suppression, while varietal selection was less effective in suppressing the weeds. Increasing seed rate of wheat (75 to 150 kg ha^{-1}) reduced weed biomass and increased grain yield by 16 to 33 per cent (Blachshaw *et al* 1996).

Christensen (1994) also observed that weed dry matter and grain yield losses were reduced as seed rate increased but the sowing dates were delayed.

Spacing

Plant spacing of course, is affected by seeding rate but the effect of crop geometry is an issue distinct from seed rate. Angiras and Sharma (1996) observed that dry matter and growth rate of *Avena fatua* was less in closer row spacing of 15 cm as compared to 20 cm row spacing. Grain yield of wheat was also higher in closer spacing of 15 cm which may be due to more competition offered by wheat and more number of effective tillers.

Sodhi and Dhaliwal (1998) at Ludhiana, reported less dry matter accumulation, less leaf area index and less number of seeds per plant of wild oats in closer spacing of 15 cm as compared to recommended spacing of 22.5 cm. Grain yield was also significantly higher at closer spacing of 15 cm. Closer row spacing (15.0 cm) of wheat significantly increased grain and straw yield as compared to crop sown at normal spacing (22.5 cm). The increase in grain yield under narrow row spacing over the normal sowing was 10.3 per cent. Closer row spacing (15.0 cm) resulted in a significant reduction in dry matter accumulation of *Phalaris* *minor* at all stages of record as compared to crop sown at normal spacing (22.5 cm) (Singh 1996). Kler and Singh (1993) reported that increase in yield of wheat both in closer and bi-directional was due to efficient utilization of incident radiation over line sowing of 22.5 cm. Similarly, it was observed that 15 cm row spacing was found superior to 20 cm spacing in intercepting light, decreasing canopy temperature and increasing grain yield (Sharma and Angiras 1996).

Sowing of wheat in both directions at closer row spacing of 15 cm is also found beneficial than sowing at 22.5 cm apart (Brar and Singh 1997). The uniform thick plant stand of wheat with resultant increase in utilization of solar energy, space and nutrient have better smothering capacity over *Phalaris minor* than thin stand due to better canopy structure (Bhan and Kumar 1998). Tomar *et al* (1999) observed that weed dry matter was minimum in closer row spacing (15 cm) followed by criss cross sowing at 22.5 x 22.5 cm which resulted in 16.8 and 13.1 per cent higher yield over unidirectional sowing.

CHAPTER-3

MATERIALS AND METHODS

The field experiment entitled "Competitive ability of wheat (*Triticum aestivum* L.) against wild oats (*Avena ludoviciana* Dur.) as influenced by date of sowing, seed rate and spacing" was conducted at the research farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* 2006-07. The details of the materials and the methods employed during the course of investigations are presented in this chapter.

Location and climate

Ludhiana is situated at an altitude of 247 meters above mean sea level at latitude of 30°56' N and longitude of 75°52' E and represents indo-gangetic alluvial plains. This tract experiences three distinct seasons in a year namely hot dry early summers followed by hot and humid monsoon period and cold winter. The mean maximum and minimum air temperatures, therefore, show considerable fluctuations during different parts of the year. Maximum temperature of 38°C are quite common during the summer and frequent frosty spell are experienced during the winter, especially in December and January. The average rainfall is 705 mm and 75 per cent of which is received during July to

September. During winters, rains are scanty but a few showers of cyclonic rains are received during December-January or late spring. The graphical representation of meteorological data recorded during the growing season of wheat has been given in Fig. 3.1 and Appendix 1. Total rainfall of 165.5 mm was received during the crop season. Data regarding crop growing season (Nov. 2006 to April 2007) have indicated that minimum temperature ranged between 4.2^{0}C to 19.4^{0}C while maximum temperature ranged between 19.5^{0}C to 36.9^{0}C. Soil temperature at 5 cm depth remained between 13.4^{0}C to 39.1^{0}C

Cropping history of the experimental field

The different crops grown on the experimental field during the previous years are given in Table 3.1.

Table 3.1 Cropping history of the field

Years	Kharif	Rabi
2001-02	Fallow	Wheat
2002-03	Green manure (Sunhemp)	Wheat
2003-04	Green manure (Sunhemp)	Wheat
2004-05	Fallow	Experimental wheat
2005-06	Fallow	Wheat
2006-07	Green manure (Dhaincha)	Experimental Wheat

Characteristics of the experimental field:

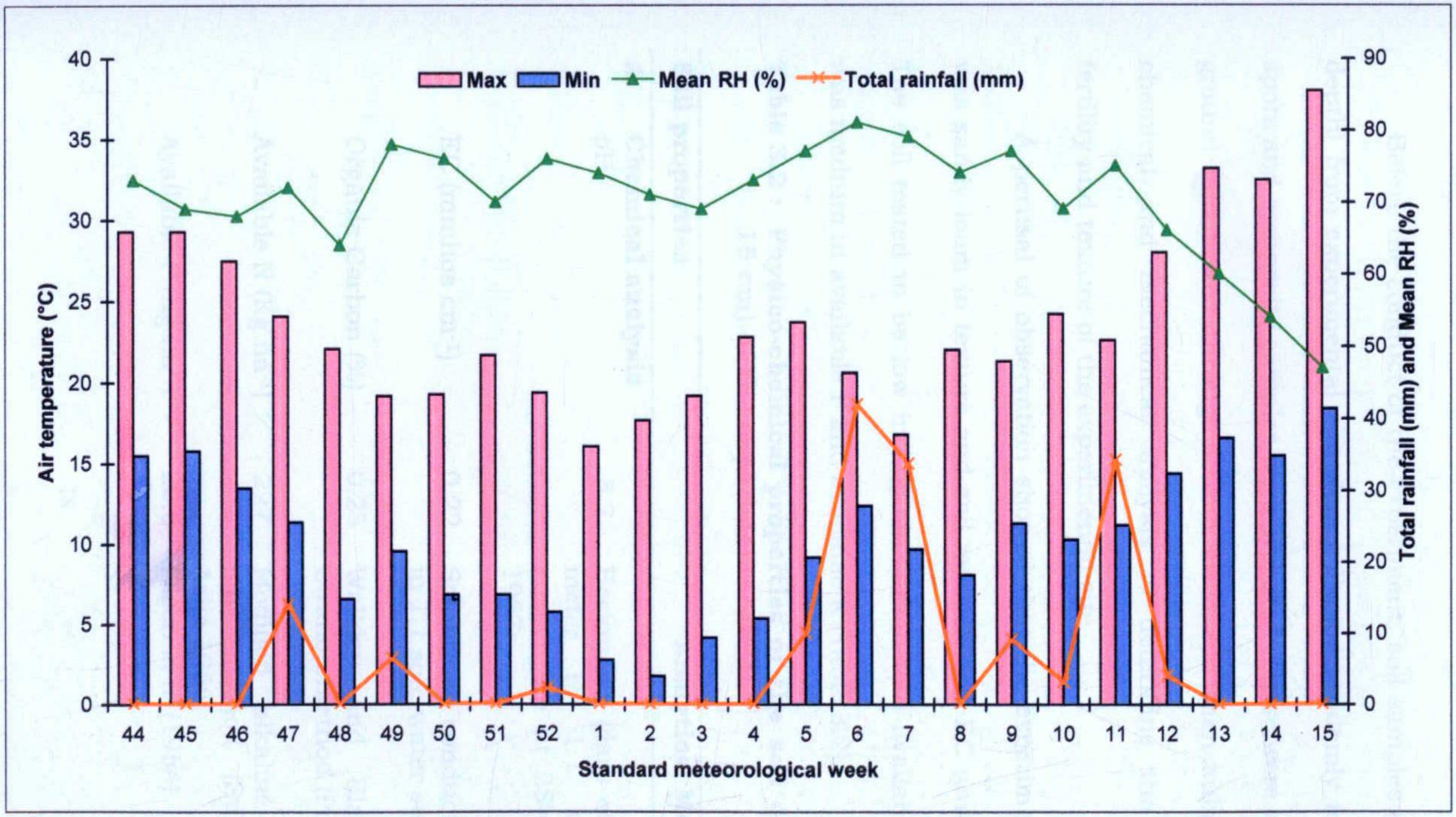


Fig. 3.1 : Weekly meteorological data recorded during the *Rabi* season 2006-2007

Before the conduct of the experiment, soil samples (0-15 cm depth) from experimental site were collected randomly from four spots and composite samples were prepared. These were air-dried, ground and sieved through 2 mm sieve and then subjected to chemical and mechanical analysis to determine the natural fertility and texture of the experimental site.

A perusal of observation showed that the experimental soil was sandy loam in texture and soil reaction and EC was normal. The soil tested to be low in organic carbon and available N but was medium in available P and available K (Table 3.2).

Table 3.2 : Physico-chemical properties of the soil depth (0-15 cm) of the experimental field

Soil properties		Analytical Method
A. Chemical analysis		
pH	8.2	Beckman's glass electrode pH meter in 1:1 soil: water suspension at 25°C (Jackson 1967)
EC (mmhos cm^{-1})	0.22	Solubridge conductivity meter in 1:1 soil: water suspension
Organic Carbon (%)	0.25	Walkley and Black's rapid titration method (Piper 1966)
Available N (Kg ha^{-1})	227	Modified alkaline permanga nate method (Subbiah and Asija 1956)
Available P (Kg ha^{-1})	20.8	Olsen *et al* (1954)

Available K (Kg ha^{-1})	185	Ammonium acetate method (Piper 1966)
B. Mechanical analysis		
Sand (%)	82.4	International pipette method (Piper 1966)
Silt (%)	9.7	- do -
Clay (%)	6.9	- do -
C. Textural class	Loamy sand	International pipette method (Piper 1966)

Layout and design

There were 24 treatments in the experiment laid out in double split plot design with date of sowing in the main plots, seed rate and spacing in the sub plots and herbicide in the sub-sub plots (Fig. 3.2).

Number of replications	:	3
Total number of plots	:	72
Gross plot size	:	14.40 m^2
Net plot size	:	8.1 m^2

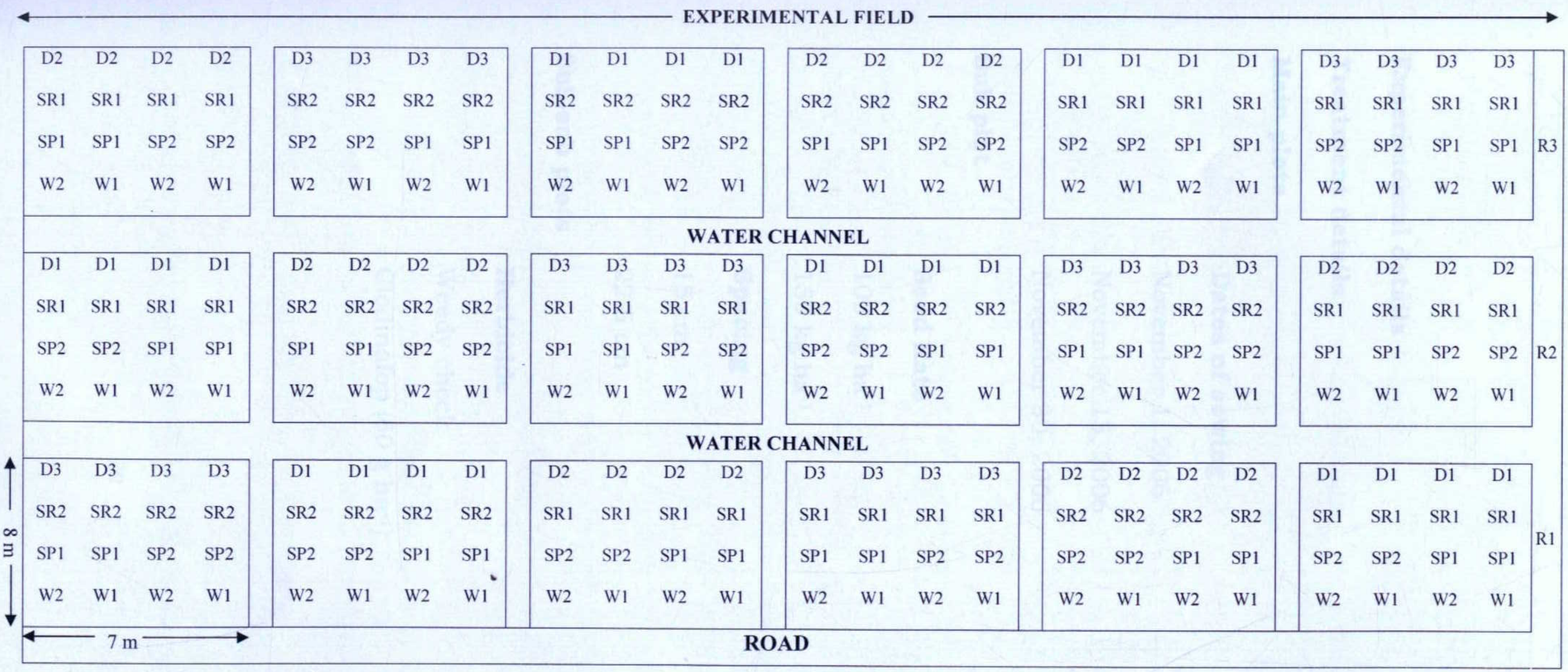
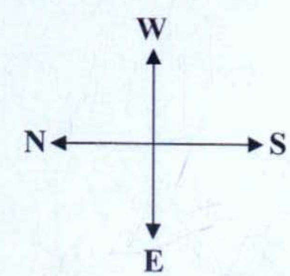


Fig. 3.2 : Layout plan of experimental field



SYMBOLS

Date of sowing
D1 : 1st November
D2 : 15th November
D3 : 30th November

Seed Rate (kg ha^{-1})
SR1 : 100
SR2 : 150

Spacing (cm)
SP1 : 15
SP2 : 22.5

Herbicide
W1 : Clodinafop 60 g ha^{-1}
W2 : Unweeded check

Experimental details

Treatment details

Main plots

Dates of sowing

November 1, 2006

November 15, 2006

November 30, 2006

Sub plot

Seed Rate

100 kg ha^{-1}

150 kg ha^{-1}

Spacing

15 cm

22.5 cm

Sub-sub plots

Herbicide

Weedy check

Clodinafop (60 g ha^{-1})

Details of the herbicide used

Technical name	Chemical formula	Trade name	Concentration
Clodinafop	(R)-2-[4-[)5-chloro-3- fluoro-2-pyridinyl)oxy] phenoxy]-propanoic acid propynyl ester (CA)	Topik	15 WP

Agronomic Practices

The details of agronomic practices followed during crop season were as under:

Field preparation

A thorough seed bed preparation was done by ploughing twice with disc harrow and once with cultivator followed by planking. A rauni (pre-sowing irrigation) was applied which was followed by two ploughings with cultivator along with twice cross planking to facilitate the preparation of fine seedbed.

Sowing

Sowing of the crop was done manually with single row hand driven seed drill on respective dates by keeping row to row spacing of 22.5 cm and 15 cm for both the seed rates.

Variety

Wheat varieties namely PBW-343 was sown on each date.

Seed rate

A seed rate of 100 kg ha^{-1} and 150 kg ha^{-1} was used for all the three dates keeping row to row spacing of 15 cm and 22.5 cm

Fertilizer

Recommended doses of nitrogen (125 kg N ha^{-1}) and phosphorus (60 kg P_2O_5 ha^{-1}) were applied through urea and DAP. Half dose of nitrogen and full dose of phosphorus was applied at the time of sowing and remaining half dose of nitrogen was top dressed after first irrigation in the respective sowing dates.

Irrigation

The first irrigation was given three weeks after sowing and subsequent irrigations were applied as per the crop requirement. During the growing season of wheat crop received five irrigations.

Herbicide

Metsulfuron was sprayed at the rate of 5 g ha^{-1} in 250 litres of water as post emergence application to control broad-leaved weeds in all plots. Clodinafop was sprayed at the rate of 60 g ha^{-1} in 250 liters of water in selected plots as per the layout.

Harvesting and threshing

Experimental crop sown on November 1, 2006 was harvested on April 10, 2007 from a net plot size of 8.1 m^2 leaving the borders, crop sown on November 15, 2006 was harvested on April 17, 2007 while the November 30, 2006 sown crop was harvested on April 21, 2007. Whole crop produce was threshed on April 23, 2007 by using engine operated thresher.

Biometric observation

A. Studies on *Avena ludoviciana*

Periodic weed count

The population of weed was recorded with the help of a quadrate measuring 30 cm x 30 cm from two locations per experimental unsprayed plots periodically.

Plant height

Five plants of *Avena ludoviciana* were selected at random from each unsprayed plot and their height was recorded periodically from ground level upto the base of flag leaf and after flowering upto the base of the panicle at different stages and average was worked out.

Dry matter accumulation

It was recorded periodically and for this purpose, *Avena ludoviciana* plants were taken from ground surface from each plot by using quadrate measuring 30 cm x 30 cm. These samples were first sun dried and then oven dried at 60°C. After weighing the sample, the dry matter accumulation was expressed as q ha^{-1}.

A. Studies on wheat crop

Plant height

Five plants per plot were randomly selected to measure the height from ground level to the base of the top most fully opened leaf and thereafter at harvesting from ground level up to the base of the ear. The plant height of five plants was averaged for statistical analysis.

Dry matter accumulation

The plant samples for the periodic dry matter accumulation were taken from 50 cm row length from two locations per plot. These samples were first sun dried and then dried in an oven at 60°C till a constant weight was obtained and the values were converted to q ha^{-1}. However, at harvest bundle weight was taken from net plot which was later converted on hectare basis (q ha^{-1})

Number of tillers

Number of tillers was counted per meter row length from randomly selected two places in each plot at different stages of crop growth.

Leaf area

The periodic leaf area at 60, 90 and 120 DAS of freshly detached leaves form crop removed from 0.5 meter row length in each plot were firstly graded into large, medium and small sized leaves. Then their number was counted and leaf area was measured with the help of leaf area meter (LICOR G2 WA). The leaf area index was then calculated by dividing the leaf area by the ground area.

Relative growth rate

Relative growth rate is also called 'efficiency index'. Relative growth rate expresses growth in terms of rate of increase in size per unit of size. RGR is analogous to the rate of compound interest earned on capital. Negative RGRs are relative decay rates. RGR was expressed as g g^{-1} day^{-1} and was calculated by the formula given by Hunt (1989).

$$RGR = \frac{\ln w_2 - \ln w_1}{t_2 - t_1}$$

Where, w_1 = Dry matter at time t_1

w_2 = Dry matter at time t_2

In = Natural log

Light interception

Penetration of photosynthetically active radiation (PAR) in the range of 0.40 to 0.70 microns (400-700 mμ) were measured between 12:00-2:00 P.M. These observations were recorded at 60, 90 and 120 days after sowing. Readings were recorded in lux 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

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

Spike length

Five spikes were selected at random from each experimental plot and the length was measured before harvest of the crop. The average length per spike was then calculated.

Number of grains per ear

For this purpose, five ear heads were selected at random from each plot in the experiment and were threshed and then number of grains was counted to compare the average number of grains per plot. The values were finally averaged to record number of grains per ear.

Thousand grain weight

This observation was recorded by taking random sample of grains from each lot and thousand grains were counted and weighed

Grain yield

Grain yield was recorded from net plot harvested (8.1m^2) as grain weight and then converted to q ha^{-1}.

Straw yield

Weight of straw was calculated after deducting grain weight from bundle weight which was recorded at the time of threshing and converted to q ha^{-1} for recording.

Chemical analysis

Samples of wheat straw and *Avena ludoviciana* were oven dried at 60°C and grinded. Grain samples were also processed for analysis.

Nitrogen

A sample of 0.5 g each of grains, wheat straw and *Avena ludoviciana* plants was digested with concentrated sulphuric acid (H_2SO_4) and digestion mixture (selenium dioxide + copper sulphate + potassium sulphate) to determine the total nitrogen content (per cent) (Piper 1966). Then the samples were analysed by modified Kjeldahl method (Jackson 1967).

Phosphorus and Potassium

A sample of 0.5 g each of grains, wheat straw and *Avena* *ludoviciana* plant was digested in the acid medium (nitric acid + perchloric acid + concentrated hydrosulphuric acid) in the ratio of 9:3:1, respectively. Phosphorus content was estimated colorimetrically by Vanadomolybdate phosphoric yellow colour method in tri acid digested sample (Jackson 1967). While for potassium estimation, tri acid digested samples were used for talking the readings from flame photometer (Jackson 1967).

TOTAL UPTAKE

Uptake by wheat (grain + straw) and *Avena ludoviciana* plants were calculated by multiplying the percentages content of these nutrients with their respective dry matter values.

STATISTICAL ANALYSIS

To test the level of significance of results, data recorded on various parameters were subjected to statistical analysis as per detailed by Cheema and Singh (1991) in statistical package CPCS-1 or by adopting the method of Gomez and Gomez (1984). All the comparisons were made at 5 per cent level of significance. The data on population and dry matter accumulation of *Avena ludoviciana* were subjected to square root transformation. Analysis of variance (ANOVA) of the experiment was as follows:

ANOVA

Source of variation	Degree of freedom
Main Plot	
Replication	2
Date of sowing (A)	2
Error (a)	4
Sub Plot	
Seed rate (B)	1
Date of sowing x Seed rate (AB)	2
Spacing (C)	1
Date of sowing x Spacing (AC)	2
Seed rate x Spacing (BC)	1
Date of sowing x Seed rate x Spacing (ABC)	2
Error (b)	18
Sub-sub plot	
Herbicides (D)	1
Date of sowing x Herbicides (AD)	2
Seed rate x Herbicides (BD)	1
Date of sowing x Seed rate x Herbicides (ABD)	2
Spacing x Herbicides (CD)	1
Date of sowing x Spacing x Herbicides (ACD)	2
Seed rate x Spacing x Herbicide (BCD)	1
Date of sowing x Seed rate x Spacing x Herbicide (ABCD)	2
Error (c)	24
Total	71

CHAPTER-4

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the experiment, conducted during *rabi* 2006-07 pertaining to growth and development of both wheat and *Avena ludoviciana* are presented in this chapter as under:

a. Effect on *Avena ludoviciana*

Weed population

Numbers of weeds per unit area indicate the intensity of weeds present in the crop. The data recorded at 60, 90, 120 days after sowing (DAS) and at harvest is presented in table 4.1. The population of *Avena ludoviciana* reduced significantly under 1st November and 30th November sown crop compared to 15th November sown crop at all the growth stages. Crop sown on 1st November and November 30th had 40.2 and 36.8 per cent reduction in weed population over November 15th sown crop at 120 DAS. Low weed population in early and late sown crop may be due to high and low temperature that was not favourable for weed emergence. Similar findings have been reported by Yaduraju and Ahuja (1997b), Singh *et al* (1997) and Panwar *et al* (1990).

Different seed rates influenced the *Avena ludoviciana* population significantly. Higher seed rate of 150 kg ha^{-1} had

Table 4.1: Effect of different treatments on periodic *A. ludoviciana* population m^{-2}

	A. ludoviciana population m^{-2}		
	Days after sowing		
Treatments	**30**	**60**	**90**
Dates of sowing			
Nov.1	3.17 (29)	3.47 (32)	3.69 (52)
Nov.15	4.20 (49)	4.58 (60)	4.87 (87)
Nov.30	3.48 (35)	3.59 (42)	3.87 (55)
C.D. (0.05)	0.71	0.48	0.63
Seed rate (Kg ha^{-1})			
100	3.68 (41)	3.99 (49)	4.40 (62)
150	3.29 (32)	3.72 (41)	4.06 (50)
C.D. (0.05)	0.29	0.26	0.34
Spacing (cm)			
15	3.21 (28)	3.62 (39)	4.17 (44)
22.5	3.60 (39)	3.87 (55)	4.38 (68)
C.D. (0.05)	0.32	0.28	0.41
Herbicide			
Clodinafop (60 g ha^{-1})	1.0 (0)	1.0 (0)	1.0 (0)
Unweeded check	7.11 (47)	6.35 (59)	7.40 (68)
C.D. (0.05)	0.17	0.22	0.27

Figures within parentheses are means of original values, data subjected to square root transformation

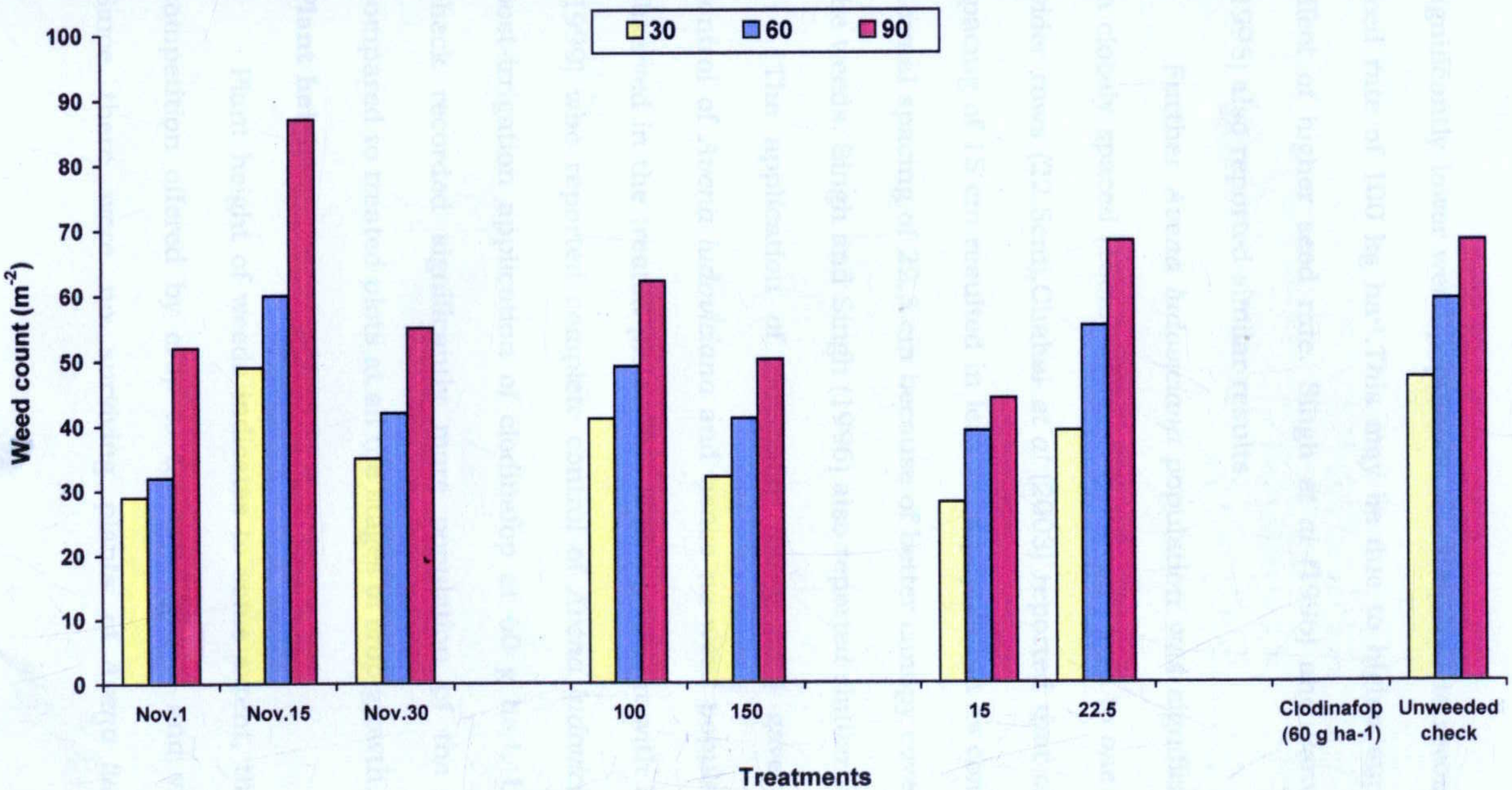


Fig. 4.1 : Effect of different treatments on periodic *Avena ludoviciana* population

significantly lower weed population as compared to recommended seed rate of 100 kg ha^{-1}.This may be due to higher suppression effect of higher seed rate. Singh *et al* (1996) and Panwar *et al* (1995) also reported similar results.

Further *Avena ludoviciana* population was significantly low in closely spaced (15cm) wheat crop as compared to one grown in wider rows (22.5cm).Chahal *et al* (2003) reported that closer row spacing of 15 cm resulted in less weed population as compared to normal spacing of 22.5 cm because of better canopy coverage over the weeds. Singh and Singh (1996) also reported similar results.

The application of clodinafop (60 g ha^{-1}) gave complete control of *Avena ludoviciana* and hence no weed population was observed in the treated plots. This is in agreement with Brar *et al* (1999) who reported complete control of *Avena ludoviciana* with post-irrigation application of clodinafop at 60 g ha^{-1}. Unweeded check recorded significantly more population of the weed as compared to treated plots at all the stages of crop growth.

Plant height

Plant height of weeds indicates to some extent, the level of competition offered by crop to the weed plants and vice-versa. Since there were no surviving plants of *Avena ludoviciana*

Table 4.2: Effect of different treatments on periodic height of *A. ludoviciana*

	Plant height (cm)			
	Days after sowing			
Treatments	**60**	**90**	**120**	**At harvest**
Dates of sowing				
Nov.1	26.5	69.2	98.7	105.2
Nov.15	34.0	80.4	103.4	110.3
Nov.30	15.2	60.1	84.3	98.4
C.D. (0.05)	3.8	7.2	4.7	4.2
Seed rate (Kg ha^{-1})				
100	24.5	68.2	89.9	109.4
150	17.1	51.3	83.4	101.7
C.D. (0.05)	4.8	8.2	5.2	4.8
Spacing (cm)				
15	22.1	64.7	97.2	104.3
22.5	20.7	63.1	95.4	102.3
C.D. (0.05)	NS	NS	NS	NS

following treatment of clodinafop (60 g ha^{-1}), the comparisons have, therefore, been made amongst the remaining treatments. The data on plant height of *Avena ludoviciana*, recorded under different treatments given in table 4.2 indicated that significantly less height was recorded in 1st November sown crop and 30th November sown crop compared to November 15 sown crop at all the stages. At crop harvest, differences with regard to plant height of *Avena ludoviciana* between 1st November (105.2 cm) and 15th November (110.3 cm) sowing dates became less apparent. Yaduraju and Ahuja (1997) reported reduction in the height of *Avena ludoviciana* with planting done in December as compared to early November planting.

The data on plant height of *Avena ludoviciana* recorded under different seed rates revealed that plant height was significantly reduced by seed rate of 150 kg ha^{-1} as compared to recommended seed rate of 100 kg ha^{-1} at all stages of observation(table4.2). This may be due to more canopy pressure and shading of *Avena ludoviciana* in higher seed rate (150 kg ha^{-1}) than the normal seed rate (100 kg ha^{-1}).

Sowing pattern of wheat affected the plant height of *Avena ludoviciana* non-significantly at all stages of observation. Similar results were reported by Sodhi and Dhaliwal (1998).

Dry matter accumulation

It is the most important parameter, which reflects the competing ability of weeds or the extent of suppression of weeds by different treatments. Dry matter of the weed was taken at different intervals of the crop growth and is presented in table 4.3. The differences among the three dates of sowing were significant at all the stages. The crop sown on 1st November resulted in significantly less dry matter production by *Avena ludoviciana* compared to 15th November and 30th November sown crop. However, at harvest 30th November sown crop recorded significantly lowest dry matter accumulation by *Avena ludoviciana* (15.2 q ha^{-1}) over 15th November (20.2 q ha^{-1}) and1st November (18.1 q ha^{-1}). At harvest, the dry matter production by *Avena ludoviciana* was reduced by 10.4 per cent in 1st November sown crop as compared to 15th November sown crop. Further, 30th November sowing registered 24.8 and 16 per cent less dry matter production by *Avena ludoviciana* in comparison to 15th November and 1st November sowing dates, respectively. The vigorous growth

Table 4.3: Effect of different treatments on periodic dry matter accumulation of *A. ludoviciana*

	Dry matter accumulation (q ha^{-1})			
	Days after sowing			
Treatments	**60**	**90**	**120**	**At harvest**
Dates of sowing				
Nov.1	1.48 (2.2)	2.45 (13.8)	2.59 (15.4)	2.79 (18.1)
Nov.15	1.87 (5.8)	2.58 (14.3)	2.87 (16.3)	2.98 (20.2)
Nov.30	1.80 (5.0)	2.49 (14.0)	2.68 (17.6)	2.54 (15.2)
C.D. (0.05)	0.15	0.12	0.16	0.09
Seed rate (Kg ha^{-1})				
100	1.54 (3.1)	2.45 (12.3)	2.63 (14.1)	2.89 (19.1)
150	1.44 (2.0)	2.13 (8.7)	2.32 (11.8)	2.50 (13.8)
C.D. (0.05)	0.11	0.09	0.08	0.10
Spacing (cm)				
15	1.31 (1.2)	2.31 (11.8)	2.51 (14.0)	2.62 (14.3)
22.5	1.58 (3.4)	2.61 (15.2)	2.75 (17.3)	2.87 (19.3)
C.D. (0.05)	0.14	0.21	0.18	0.21
Herbicide				
Clodinafop (60 g ha^{-1})	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Unweeded check	2.57 (4.8)	3.98 (14.7)	4.48 (18.3)	4.68 (21.8)
C.D. (0.05)	0.06	0.07	0.09	0.13

Figures within parentheses are means of original values, data subjected to square root transformation

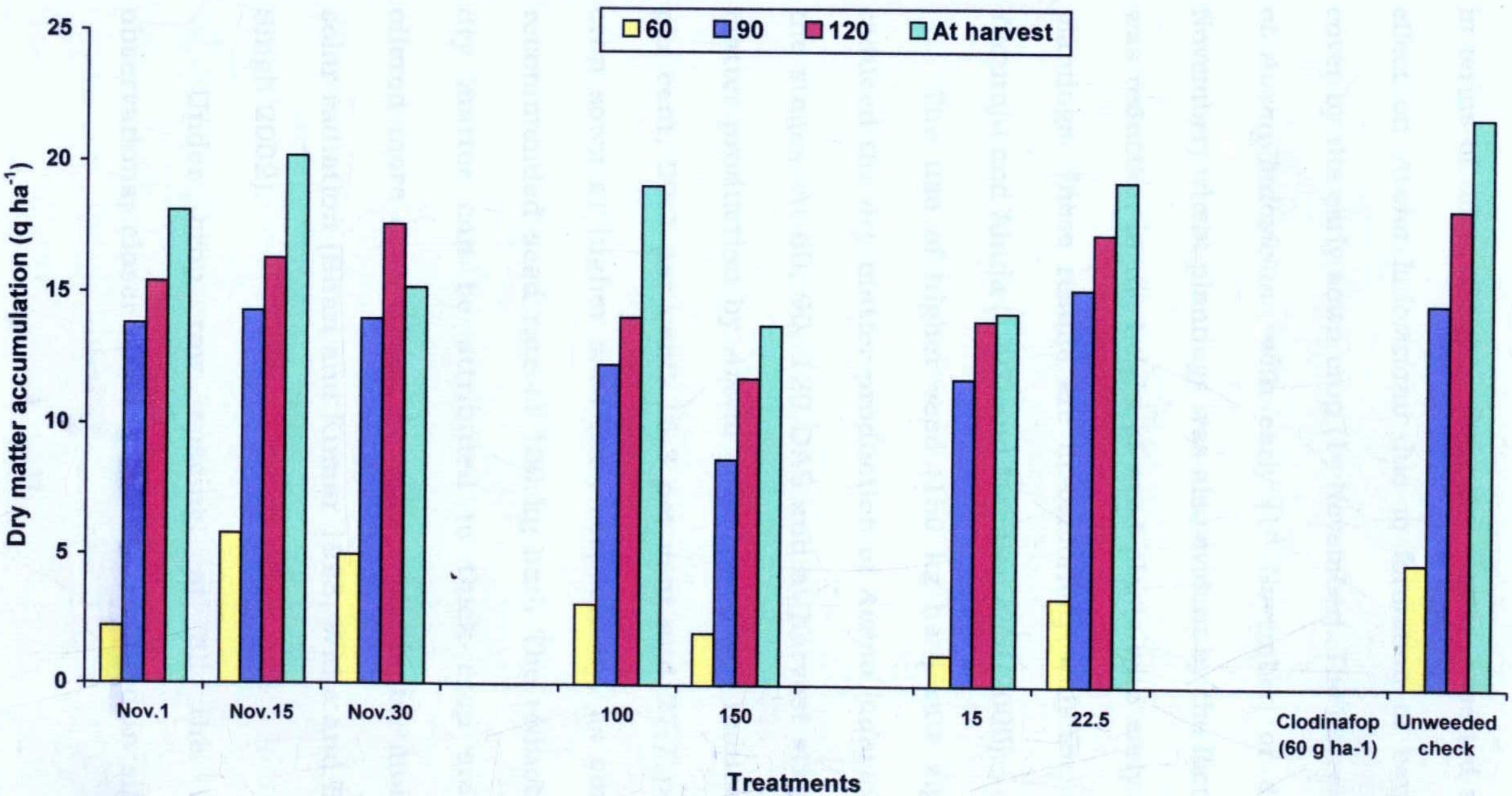


Fig. 4.2 : Effect of different treatments on periodic dry matter accumulation of *A. ludoviciana*

in terms of tillers aided by more dry matter, asserted smothering effect on *Avena ludoviciana* due to formation of better canopy cover by the early sown crop (1st November). The decreased vigour of *Avena ludoviciana* with early (1st November) or delayed (30 November) wheat plantings was also evident by the fact that there was reduction in the height of weed plants with early or delayed plantings. These results are in conformity with the findings of Yaduraju and Ahuja (1997) and Mahajan *et al* (2000).

The use of higher seed (150 kg ha^{-1}) rate significantly reduced the dry matter production of *Avena ludoviciana* at all the stages. At 60, 90, 120 DAS and at harvest stage, the dry matter production by *Avena ludoviciana* was reduced by 35.5 per cent, 29.3 per cent, 16.3 per cent and 27.7 per cent in crop sown at higher seed rate, respectively, as compared to recommended seed rate of 100 kg ha^{-1}. The reduction in the dry matter can be attributed to thick crop stand which offered more competition for space, nutrients, moisture and solar radiation (Bhan and Kumar 1998, Walia and Brar 2001, Singh 2002).

Under crop row spacing, at all the stages of observations, closer spacing (15 cm) resulted in significantly less dry matter accumulation by *Avena ludoviciana* over 22.5 cm spacing. At 60, 90, 120 DAS and at harvest stage, the dry matter production of *Avena ludoviciana* under 15 cm spacing was reduced to the extent of 64.7, 22.4, 19.1 and 25.9 per cent, respectively, compared to 22.5 cm row to row spacing. Thus, increasing the crop plants through better distribution of crop plants per unit area greatly facilitated weed suppression by maintaining dominance over weeds through modification of its canopy (Chahal *et al* 2003, Brar and Singh 1997, Angiras and Sharma 1996).

The data showed that post-emergence application of clodinafop (60 g ha^{-1}) resulted in the complete kill of the emerged plants of *Avena ludoviciana* and hence recorded nil growth by the weed compared to unweeded plots.

It was noticed that interaction effects between dates of sowing and seed rate were significant at harvest and are presented in table 4.4 in which wheat crop when sown on 30th November showed pronounced effect in suppressing the growth of *Avena ludoviciana* particularly with seed rate of 150 kg ha^{-1}. The differences in dry matter accumulation by *Avena ludoviciana* between first two dates was non-significant with

Table 4.4: Interaction effect of different treatments on the dry matter accumulation ($q\ ha^{-1}$) by *Avena ludoviciana* at harvest

	Date of sowing		
Seed rate	**Nov 1**	**Nov 15**	**Nov 30**
100 kg/ha	2.49 (12.4)	2.61 (15.1)	2.20 (10.1)
150 kg/ha	2.40 (11.2)	2.52 (13.2)	2.05 (9.3)

Interaction CD (0.05) = 0.17

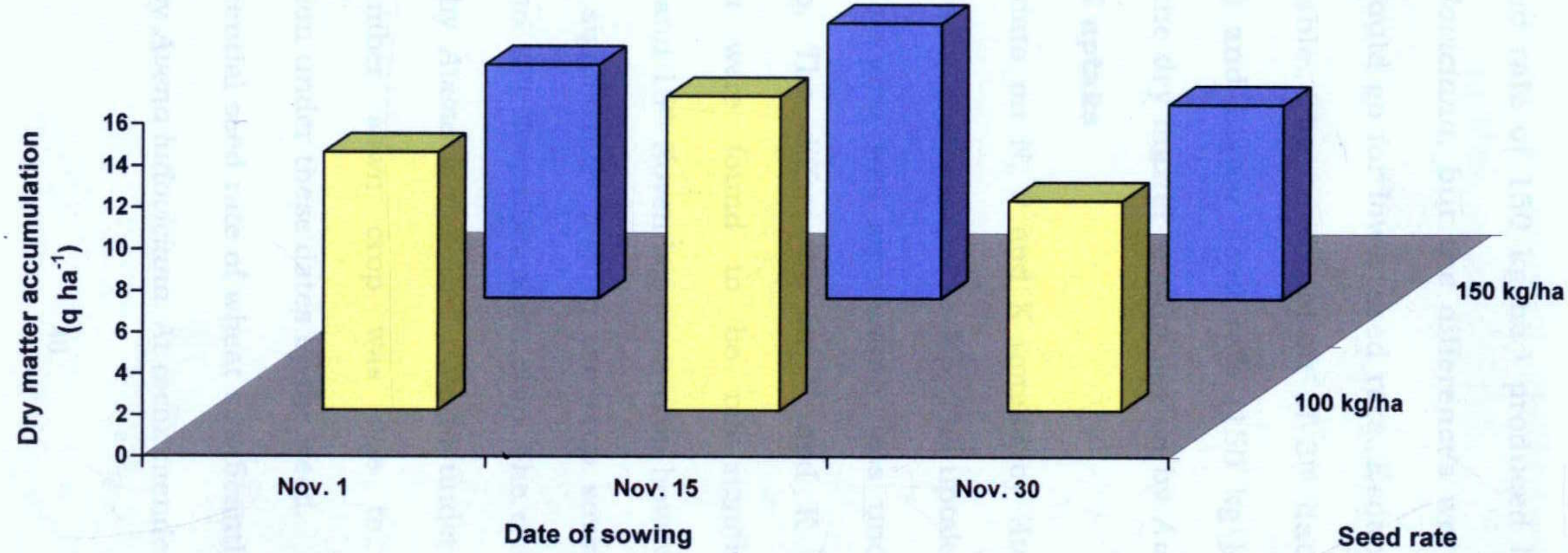


Fig. 4.3 : Interaction effect of dates of sowing and seed rate for dry matter accumulation of *Avena ludoviciana* at harvest

both the seed rates. Under all the three dates of sowing, higher seed rate of 150 kg ha^{-1} produced less dry matter of *Avena ludoviciana*, but the differences were non significant. So one should go for lower seed rate. Economically, less seed rate is viable. The combination of 3rd date of sowing (30th November) and higher seed rate (150 kg ha^{-1}) was best for reducing the dry matter accumulation by *Avena ludoviciana.*

N, P and K uptake

The data on N, P and K uptake by *Avena ludoviciana* at harvest is enumerated in table 4.5. The uptake of N, P and K by *Avena ludoviciana* was significantly less under 30th November sown crop. The differences in N and K uptake by *Avena ludoviciana* were found to be non-significant between 1st November and 15th November sown crop however P uptake by the weed was significantly less in the crop sown on 1st November compared to 15th November sown crop. The reduction in N, P and K uptake by *Avena ludoviciana* noticed under 1st November and 30th November sown crop was due to less dry matter accumulation under these dates by the weed.

Differential seed rate of wheat significantly affected N, P and K uptake by *Avena ludoviciana.* At recommended seed rate of 100

Table 4.5: Effect of different treatments on nutrient uptake of N, P and K by *A. ludoviciana*

	Nutrient uptake (kg ha^{-1})		
Treatments	**N**	**P**	**K**
Dates of sowing			
Nov.1	22.30	2.96	32.10
Nov.15	25.07	3.57	35.08
Nov.30	19.10	2.17	24.76
C.D. (0.05)	3.27	0.31	3.17
Seed rate (Kg ha^{-1})			
100	26.40	3.47	33.11
150	21.17	3.08	30.70
C.D. (0.05)	2.96	0.28	3.31
Spacing (cm)			
15	22.71	3.21	30.22
22.5	25.80	3.62	33.18
C.D. (0.05)	3.12	0.32	3.08

kg ha^{-1} the N uptake was 5.33 kg ha^{-1} higher than 150 kg ha^{-1} seed rate. The P and K uptake by *Avena ludoviciana* at lower seed rate of 100 kg ha^{-1} was 11.2 percent and 7.27 per cent more than higher seed rate of 150 kg ha^{-1} respectively. Bhullar and Walia (2003) reported that uptake of N, P and K by weed decreased in crop raised with higher seed rate of 150 kg ha^{-1} as compared to crop raised with recommended seed rate of 100 kg ha^{-1}.

Spacing also affected the uptake of N, P and K by *Avena ludoviciana* significantly. At normal recommended spacing of 22.5 cm the N, P, K uptake was significantly lowered than the closer spacing of 15 cm. This may be due to less weed population and less dry matter accumulation by *Avena ludoviciana* at closer spacing. The decrease in N, P and K uptake was 3.09, 0.41 and 2.96 kg ha^{-1} at closer spacing of 15 cm as compared to normal recommended spacing of 22.5 cm. These results are in conformity with the findings of Kaur and Bajwa (2001).

b. Effect on crop

Plant height

Plant height is one of the indices for determining the growth and suppressing ability of the crop, if any, on the weeds. This parameter also reflects the suppressing ability of crop/cultivar.

Table 4.6: Effect of different treatments on periodic height of wheat

	Plant height (cm)			
	Days after sowing			
Treatment	60	90	120	At harvest
Dates of sowing				
Nov.1	37.4	61.2	84.9	85.3
Nov.15	25.7	59.0	81.3	93.1
Nov.30	18.2	53.0	75.4	81.9
C.D. (0.05)	2.64	NS	3.24	3.94
Seed rate (Kg ha^{-1})				
100	20.4	53.4	80.4	87.0
150	23.9	59.2	83.3	91.4
C.D. (0.05)	1.92	1.71	2.1	3.10
Spacing (cm)				
15	19.3	54.5	78.2	86.1
22.5	22.4	53.7	80.4	89.7
C.D. (0.05)	1.4	NS	NS	NS
Herbicide				
Clodinafop (60 g ha^{-1})	27.4	58.5	77.4	91.4
Unweeded check	28.9	58.0	82.3	92.3
C.D. (0.05)	NS	NS	1.83	NS

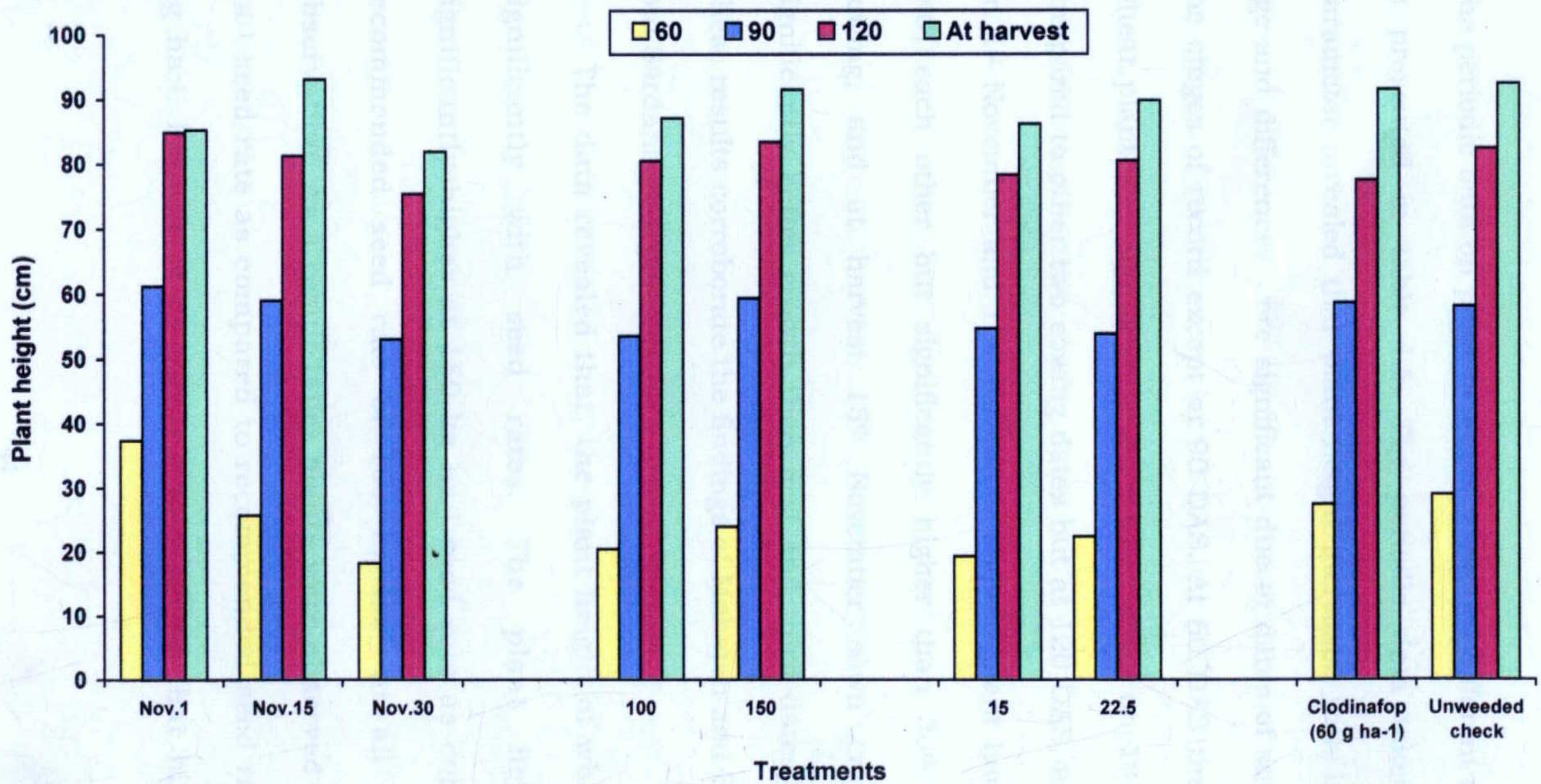


Fig. 4.4 : Effect of different treatments on periodic height of wheat

The periodic data on plant height of wheat for different treatments is presented in table 4.6. The periodic data taken on this parameter revealed that plant height increased with increase in age and differences were significant due to dates of sowing at all the stages of record except at 90 DAS. At 60 DAS the height of wheat plant was significantly more when sown on 1st November compared to other two sowing dates but at 120 DAS, wheat sown on 1st November and 15th November showed plant height at par with each other but significantly higher than 30th November sowing, and at harvest 15th November sown crop showed significantly better growth than first and third dates of sowing. These results corroborate the findings of Mahajan and Brar (2001) and Sardana *et al* (2002).

The data revealed that, the plant height of wheat varied significantly with seed rates. The plant height was significantly higher at 150 kg ha^{-1} seed rate as compared to recommended seed rate of 100 kg ha^{-1} at all stages of observation. As a result taller plants were observed in 150 kg ha^{-1} seed rate as compared to recommended seed rate of 100 kg ha^{-1}. Panwar *et al* (1995) also reported that higher seed rate of 150 kg ha^{-1} recorded taller plants over seed rate of 100 kg ha^{-1}.

Row spacing had no significant influence on the plant height of wheat at all stages of record except at 60 DAS. Closer spacing (15 cm) recorded less height compared to normal spacing (22.5 cm) at all the periodic observations but the differences were not significant, except at 60 days of sowing where normal spacing had significantly higher plant height (22.4) than closer spacing (19.3). The results found were in concordance with the findings of Singh *et al* (2003).

The data showed that unweeded plots tended to produce taller plants as compared to herbicide treated plots however the differences were statistically non-significant at all the stages except at 120 DAS. Similar findings were reported by Sodhi and Dhaliwal (1998).

Dry matter accumulation

Dry matter accumulation by crop is one of the most important growth parameters to be considered while assessing the effect of different treatments and competitive ability of the crop with weeds.

The data in table 4.7 showed that at all the stages of crop growth dry matter accumulation by wheat crop increased significantly under 1st November sown crop as compared to 15th November and 30th November sown crop. The dry matter production of crop at harvest stage, under 1st November sowing increased by 16 and 19.5 per cent over 15th November and 30th November sowing, respectively. However, at harvest the later dates of sowing (15th November and 30th November) were at par with each other in respect of dry matter production by the crop. Singh *et al* (1997) and Virk (2001) observed higher dry matter accumulation by the crop in October sowing compared to early November or late November sowing.

At all the stages of crop growth the dry matter accumulation by wheat crop increased significantly at higher seed rate (150 kg ha^{-1}) as compared to recommended seed rate (100 kg ha^{-1}). At 60, 90 and 120 DAS and at harvest the dry matter production at seed rate of 150 kg ha^{-1} increased to the tune of 12.1 percent, 20.7 percent, 25.4 percent and 16.8 percent, respectively over recommended seed rate of 100 kg ha^{-1}. The increase in the dry matter can be attributed to the better suppression of *Avena ludoviciana* at higher seed rate

Table 4.7: Effect of different treatments on periodic dry matter accumulation of wheat

	Dry matter accumulation (q ha^{-1})			
	Days after sowing			
Treatments	**60**	**90**	**120**	**At harvest**
Dates of sowing				
Nov.1	25.3	52.7	69.8	114.7
Nov.15	23.1	46.2	58.3	96.3
Nov.30	17.5	41.9	54.2	92.3
C.D. (0.05)	1.43	3.21	5.09	6.23
Seed rate (Kg ha^{-1})				
100	23.1	45.3	63.71	100.3
150	25.9	54.7	79.87	117.2
C.D. (0.05)	1.64	5.2	7.11	7.13
Spacing (cm)				
15	28.0	53.2	67.11	98.3
22.5	25.3	48.3	59.23	89.3
C.D. (0.05)	1.3	3.7	3.11	5.94
Herbicide				
Clodinafop (60 g ha^{-1})	24.1	55.3	70.6	123.4
Unweeded check	17.2	38.3	54.2	80.5
C.D. (0.05)	1.34	2.19	2.37	2.87

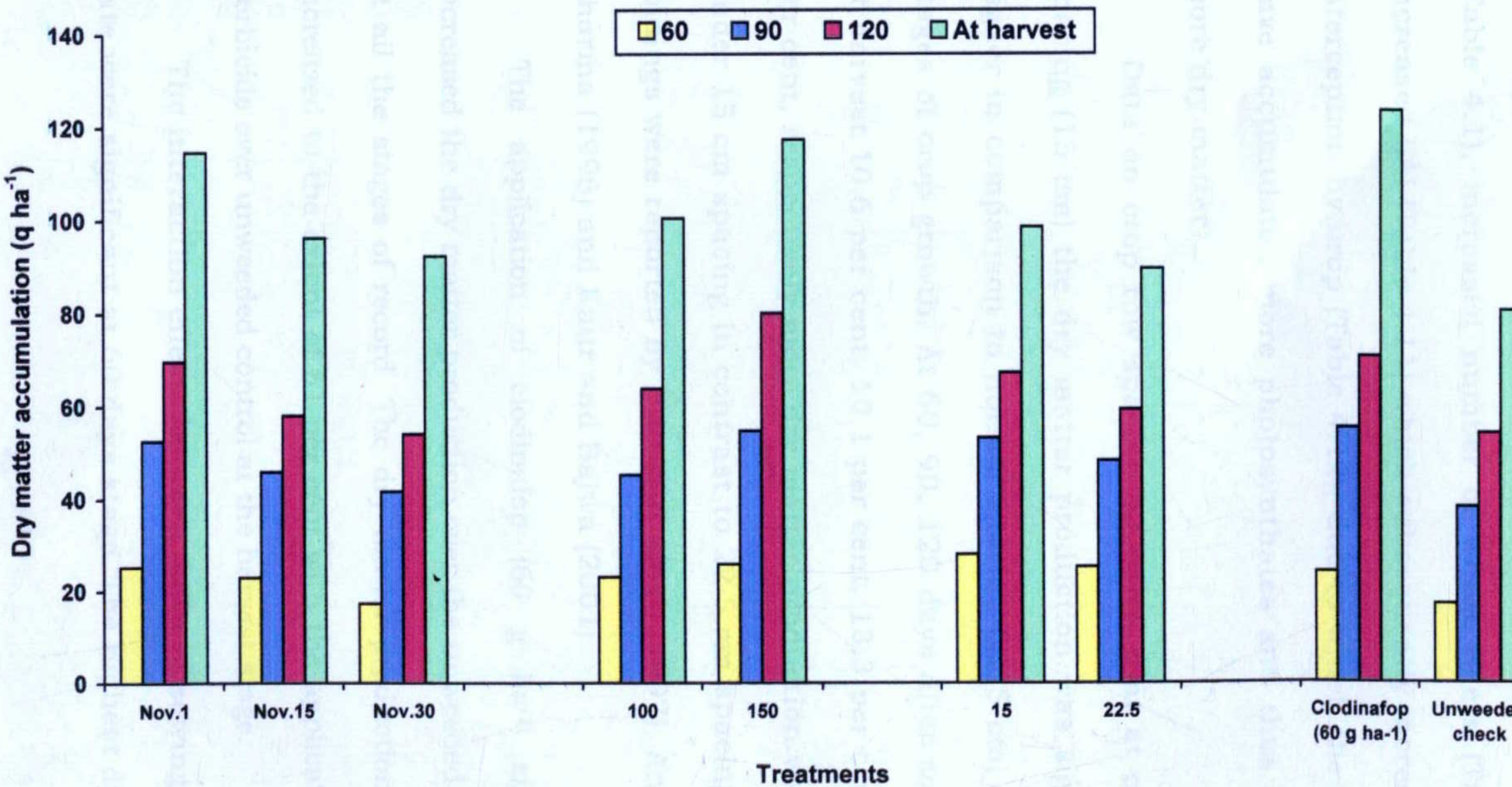


Fig. 4.5 : Effect of different treatments on periodic dry matter accumulation of wheat

(Table 4.1), increased number of wheat tillers (Table 4.9), increased LAI (Table 4.11) which subsequently increased light interception by crop (Table 4.12), due to which the crop may have accumulated more photosynthates and thus produced more dry matter.

Data on crop row spacing indicated that at closer row spacing (15 cm) the dry matter production was significantly higher in comparison to normal spacing (22.5 cm) at all the stages of crop growth. At 60, 90, 120 days after sowing and at harvest 10.6 per cent, 10.1 per cent, 13.3 per cent and 10 per cent, respectively more dry matter production was noticed under 15 cm spacing in contrast to 22.5 cm spacing. Similar findings were reported by Brar and Singh (1997), Angiras and Sharma (1996) and Kaur and Bajwa (2001).

The application of clodinafop (60 g ha^{-1}) significantly increased the dry matter production over the unweeded treatment at all the stages of record. The dry matter production of wheat increased to the extent of 51 per cent with the application of the herbicide over unweeded control at the harvest stage.

The interaction effects between dates of sowing and seed rate were significant at 60 days stage. The highest dry matter

Table 4.8: Interaction effect of different treatments on the dry matter accumulation (q ha^{-1}) by wheat at 60 DAS

	Date of sowing		
Seed rate	**Nov 1**	**Nov 15**	**Nov 30**
100 kg/ha	26.4	24.1	19.2
150 kg/ha	28.4	25.5	21.7

Interaction CD (0.05) = 2.24

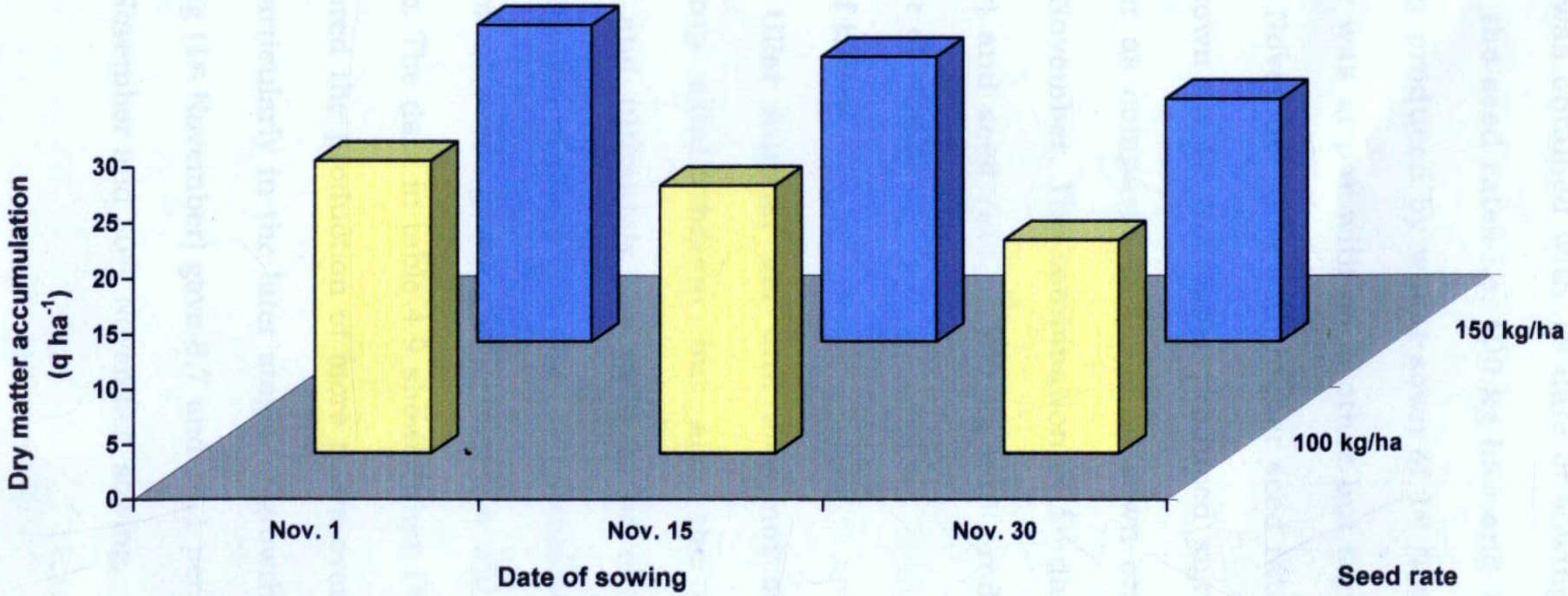


Fig. 4.6 : Interaction effect of different treatments on the dry matter accumulation by wheat at 60 DAS

of wheat was obtained with 1st date of sowing (1st November) with both the seed rates i.e. 100 kg ha^{-1} and 150 kg ha^{-1}. The dry matter produced by wheat sown of 1st November and 15th November was at par with each other but significantly better than 30th November. But with higher seed rate i.e. 150 kg ha^{-1} wheat sown on 1st November produced significantly higher dry matter as compared to the crop sown on 15th November and 30th November. The combination of 1st date of sowing (1st November) and seed rate of 150 kg ha^{-1} produced maximum dry matter of wheat.

Number of tillers

The tiller number per unit area not only reflects the proper crop establishment but also the desired canopy structure and ultimately the yield to be obtained from the crop. Production of tillers of a plant in cereals is related with the suppression of weeds growing in association with it and the yield of the crop. The data in table 4.9 showed that 1st November sown crop favoured the production of more tillers over the subsequent sowings particularly in the later stages of growth. At harvest, the first sowing (1st November) gave 8.7 and 14.1 per cent more tillers over 15th November and 30th November sowing, respectively. The

Table 4.9: Effect of different treatments on periodic number of tillers per metre row length of wheat

	Number of tillers per metre row length			
	Days after sowing			
Treatments	**60**	**90**	**120**	**Effective tillers**
Dates of sowing				
Nov.1	88.9	93.1	95.2	85.2
Nov.15	87.3	90.3	83.1	78.4
Nov.30	78.4	85.2	84.2	74.7
C.D. (0.05)	2.34	1.67	2.34	2.18
Seed rate (Kg ha^{-1})				
100	84.3	93.2	92.1	85.2
150	94.7	100.4	98.4	93.4
C.D. (0.05)	2.86	3.12	3.27	2.91
Spacing (cm)				
15	96.3	98.4	95.4	93.2
22.5	90.4	92.7	91.2	89.3
C.D. (0.05)	2.13	2.41	2.11	1.98
Herbicide				
Clodinafop (60 g ha^{-1})	95.2	94.2	90.4	87.2
Unweeded check	71.4	75.4	78.2	74.3
C.D. (0.05)	1.69	1.78	1.93	1.27

favourable effect on the tillering in case of early sown crop was also reflected in the production of higher dry matter accumulation by the crop to tune of 16 and 19.5 per cent over 15th November and 30th November sowings, respectively. Virk *et al* (2003) also reported similar results.

The data showed that number of tillers were significantly higher at higher seed rate (150 kg ha^{-1}) as compared to recommend seed rate (100 kg ha^{-1}) at all the stages of observation. At 60, 90, 120 DAS and at harvest the increase in number of tillers were 12.3 per cent, 8 per cent, 7 per cent and 10 per cent, respectively in crop sown at higher seed rate (150 kg ha^{-1}) as compared to normal seed rate. The increase in number of tillers may be due to the higher seedling emergence and more light interception (Table 4.12). The similar results were observed by Walia and Brar (2001).

Crop sown at closer row spacing of 15 cm recorded significantly higher number of tillers as compared to normal spacing of 22.5 cm. At closer row spacing the increase in number of tillers at 60, 90 and 120 DAS and at harvest was 6 per cent, 6 per cent, 5 per cent and 4 per cent, respectively over normal spacing of 22.5 cm. At closer row spacing, number of plants per unit area increased and hence there was an increase in the number of tillers at all the stages of record. Similar results were observed Angiras and Sharma (1996).

The application of clodinafop (60 g ha^{-1}) significantly increased the number of tillers as compared to unweeded control and the increase was to the tune of 17.4 per cent.

Relative growth rate (RGR)

The data (Table 4.10) revealed that 30th November sown crop had significantly higher relative growth rate than that of 1st November and 15th November sown crop at 60 and 120 DAS, However, At 90 DAS relative growth rate was significantly higher in 1st November sown crop than 30th November sown crop but statistically, at par with 15th November sown crop.

RGR is significantly more in higher seed rate (150 kg ha^{-1}) at all the crop growth stages (60, 90 and 120 DAS) as revealed by the data on relative growth rate at different crop growth stages.

The data for relative growth rate at different row spacing showed significantly higher RGR at closer row spacing (15 cm) at 60 and 120 DAS but it is non-significant in case of 90

Table 4.10: Effect of different treatments on periodic relative growth rate (RGR) of wheat

	Relative growth rate $g\ g^{-1} day^{-1}$		
	Days after sowing		
Treatments	**60**	**90**	**120**
Dates of sowing			
Nov.1	0.0205	0.0113	0.0150
Nov.15	0.0211	0.0108	0.0134
Nov.30	0.0267	0.0094	0.0164
C.D. (0.05)	0.0053	0.0007	0.0013
Seed rate (Kg ha^{-1})			
100	0.0232	0.0110	0.0147
150	0.0239	0.0114	0.0158
C.D. (0.05)	0.0006	0.0003	0.0008
Spacing (cm)			
15	0.0241	0.0113	0.0149
22.5	0.0253	0.0110	0.0161
C.D. (0.05)	0.0019	NS	0.0009
Herbicide			
Clodinafop (60 g ha^{-1})	0.0239	0.0098	0.0169
Unweeded check	0.0227	0.0117	0.0119
C.D. (0.05)	0.0008	0.0018	0.0028

DAS as compared to normal recommended spacing of 22.5 cm.

Further the data indicated that the use of herbicide for the control *Avena ludoviciana* registered significantly higher RGR as compared to untreated crop at harvest while at 120 DAS the trend was reverse and at 90 DAS differences were not significant statistically.

Leaf area index (LAI)

Leaf area index (LAI) is a good index of crop growth and a major character influencing assimilating capacity of crop. LAI below optimum results in lesser interception of solar radiation and may affect the yield of the crop.

The planting dates had significant influence on the LAI of the crop. As it is evident from the table 4.11, 1st November sown crop had a leaf area index significantly higher than that of 15th November and 30th November sown crop at 90 and 120 DAS while at 60 DAS it had leaf area index at par with 15th November sown crop. Mahajan (2000) has reported that early sown crop had more LAI than late sown crop.

Higher seed rate (150 kg ha^{-1}) recorded significantly higher LAI as compared to recommended seed rate

Table 4.11: Effect of different treatments on periodic leaf area index (LAI) of wheat

	Leaf Area Index (LAI)		
	Days after sowing		
Treatments	**60**	**90**	**120**
Dates of sowing			
Nov.1	2.52	4.11	3.31
Nov.15	2.45	3.81	2.54
Nov.30	2.09	3.70	2.39
C.D. (0.05)	0.09	0.04	0.06
Seed rate (Kg ha^{-1})			
100	2.43	3.94	3.28
150	2.59	4.18	3.48
C.D. (0.05)	0.12	0.06	0.09
Spacing (cm)			
15	2.39	3.98	3.47
22.5	2.27	3.64	3.24
C.D. (0.05)	0.07	0.08	0.09
Herbicide			
Clodinafop (60 g ha^{-1})	2.32	3.87	2.69
Unweeded check	2.21	3.51	2.57
C.D. (0.05)	0.04	0.13	0.04

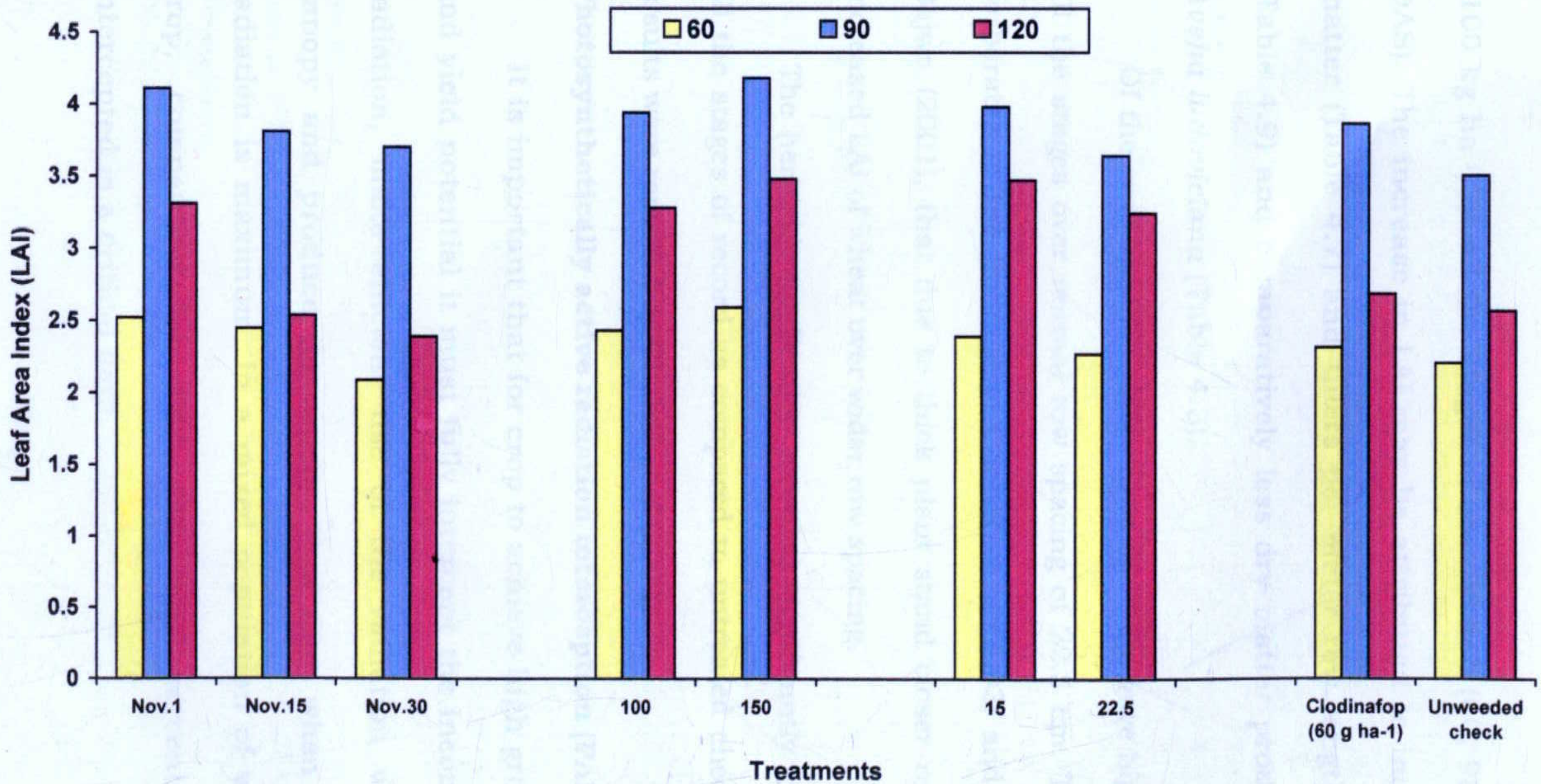


Fig. 4.7 : Effect of different treatments on periodic leaf area index (LAI) of wheat

(100 kg ha^{-1}) at all the stages of observation (60, 90 and 120 DAS). The increase in LAI may be attributed to increase dry matter (Table 4.7) and tillers per meter row length by crop (Table 4.9) and comparatively less dry matter production by *Avena ludoviciana* (Table 4.3).

Of the crop spacing, closer rows of 15 cm gave higher LAI at all the stages over normal row spacing of 22.5 cm. The results corborates to the findings of Chahal *et al* (2003) and Kaur and Bajwa (2001), that due to thick plant stand closer row spacing increased LAI of wheat over wider row spacing.

The herbicide application recorded significantly more LAI at all the stages of record as compared to untreated check. Similar results were reported by Chahal *et al* (2003).

Photosynthetically active radiation interception (PARI)

It is important that for crop to achieve high growth rates and yield potential it must fully intercept the incoming solar radiation, make efficient use of the radiation within the canopy and produce its canopy at a time when incoming radiation is maximum. In a mixed population of weeds and crop, competition for light and thus percentage light intercepted is a critical data.

Table 4.12: Effect of different treatments on periodic PAR interception

	PAR interception (%)		
	Days after sowing		
Treatments	**60**	**90**	**120**
Dates of sowing			
Nov.1	79.2	88.3	85.4
Nov.15	63.4	79.2	77.2
Nov.30	49.7	74.2	78.4
C.D. (0.05)	6.37	3.84	1.74
Seed rate (Kg ha^{-1})			
100	68.4	78.4	74.3
150	73.4	85.7	84.1
C.D. (0.05)	2.37	3.29	3.51
Spacing (cm)			
15	65.4	75.4	70.3
22.5	59.3	71.3	68.2
C.D. (0.05)	3.77	4.17	1.45
Herbicide			
Clodinafop (60 g ha^{-1})	58.3	73.2	71.7
Unweeded check	66.7	84.6	82.8
C.D. (0.05)	2.17	1.89	1.81

It was observed that photosynthetically active radiation interception was significantly influenced by sowing dates (Table 4.12). PARI was significantly more under first date i.e. 1st November sown crop due to more leaf area index than 15th November and 30th November sown crop at all the stages of crop growth. Hence, *Avena ludoviciana* plants were deprived of incident radiations resulting in its lesser growth under 1st November sown crop. Similar findings were reported by Virk *et al* (2003).

Light interception was significantly more at higher seed rate (150 kg ha^{-1}) in contrast to recommended seed rate (100 kg ha^{-1}) at all the stages of crop (60, 90 and 120 DAS). The increased light interception at higher seed rate of 150 kg ha^{-1} may be due to the increased number of tillers (Table4.9), more LAI (Table 4.11) and dense crop stand.

Closer row (15 cm) at both the stages of observation recorded significantly high percentage of light interception as compared to wider row (22.5cm) spacing. At closer row spacing there was increased number of plants per unit area and thus thick plant stand resulted in more light interception. Similar results were observed by Sodhi and Dhaliwal (1998) and Chahal *et al* (2003).

Untreated plots intercepted more PAR than the treated plots as mixed canopy of crop and the weeds had a high proportion of foliage concentrated near the top. This is in conformity with the findings of Thomas and Yaduraju (1999) and Chahal *et al* (2003).

Yield contributing characters

a) Spike length: Spike length or ear head length is an important yield attributing character which is directly associated with the number of grains per ear and thus holds significance in determining the grain yield. Data (table 4.13) revealed that 1st November sowing produced significantly longest spike when compared with 15th November and 30th November sowing.

A perusal of data in table 4.13 revealed that higher seed rate (150 kg ha^{-1}) produced significantly longer spike as compared to recommended seed rate (100 kg ha^{-1}).

Row spacing did not influence the spike length significantly. Similar results were reported by Singh and Singh (1996) and Singh *et al* (2003).

The spike length was significantly less under unweeded check in comparison to clodinafop (60 g ha^{-1}) treated plots.

b) Number of grains per ear: This character that depends primarily on the size of the ear head, followed a similar pattern of variation as the ear length. Data pertaining to number of grains per spike showed that grains per spike were significantly more under 1st November sowing as compared to 15th November and 30th November sowing while the latter dates of sowing were at par. Sardana *et al* (2002) also reported similar findings.

Grains per spike were significantly more at higher seed rate (150 kg ha^{-1}) as compared to recommended seed rate (100 kg ha^{-1}). The increase in number of grains was about 9 per cent in higher seed rate (150 kg ha^{-1}) as compared to normal seed rate. Sodhi and Dhaliwal (1998) also reported similar results.

Row spacing significantly influenced the number of grains per spike. Number of grains per spike is significantly higher in case of closer plant spacing of 15 cm as compared to recommended plant spacing of 22.5 cm. The increase in number of grains per ear was about 5 per cent in closer spacing (15 cm) as compared to normal spacing (22.5 cm). Singh and Singh (1996) also reported similar results.

The number of grains per ear was significantly more in the weed free crop when compared with weedy crop.

c) 1000-grain weight (test weight)

This parameter shows the boldness/size of grains. It was noticed that the influence of time of sowing on test weight was significant. Test weight increased significantly under 1st November sown crop in comparison to 15th November and 30th November sown crop. Singh *et al* (1997) and Sardana *et al* (2002) also observed similar results.

The data further reveals that influence of seed rate on test weight was significant. Test weight was significantly higher in seed rate of 150 kg ha^{-1} as compared to seed rate of 100 kg ha^{-1}. The increase of test weight in higher seed rate was about 7 per cent.

Row spacing significantly influenced the thousand grain weight. Thousand grain weight was significantly higher in case of closer plant spacing (15 cm) as compared to recommended plant spacing (22.5 cm). The thousand grain weight was about 7 per cent higher in closer spacing (15 cm) as compared to normal recommended spacing (22.5 cm). Singh and Singh (1996) also reported similar results.

The herbicide application significantly increased the test weight of the crop as compared to the untreated crop.

Table 4.13: Effect of different treatments on yield contributing characters of wheat

Treatments	Spike length (cm)	Grains/ear (No.)	1000 grain weight (g)
Dates of sowing			
Nov.1	11.4	51.4	45.4
Nov.15	9.8	42.3	36.4
Nov.30	8.3	40.3	28.9
C.D. (0.05)	0.91	3.07	6.41
Seed rate (Kg ha^{-1})			
100	8.7	46.3	38.9
150	10.8	50.4	41.8
C.D. (0.05)	0.82	2.74	2.89
Spacing (cm)			
15	12.1	48.9	42.3
22.5	11.7	46.4	39.4
C.D. (0.05)	NS	2.13	1.72
Herbicide			
Clodinafop (60 g ha^{-1})	10.7	48.8	43.8
Unweeded check	9.2	41.7	34.7
C.D. (0.05)	0.43	2.03	1.98

Grain yield

Grain yield, a net result of the interaction of various factors is a major criterion for judging and comparing the efficiency of different treatments. The data with respect to this parameter is presented in table 4.14. The crop sown on 1st November had a competitive edge over *Avena ludoviciana* as compared to the crop sown on subsequent dates and recorded reduction in growth parameters such as density, dry matter accumulation of *Avena ludoviciana*. Thus, due to an upper hand in competition with *Avena ludoviciana*, early sown crop had more number of tillers, more number of grains per ear and more test weight and ultimately the favourable effect was reflected on the grain yield of the crop and therefore 1st November sown crop yielded significantly more to the tune of 7.9 and 21.6 per cent over 15th November and 30th November sown crop, respectively. Virk *et al* (2003) also reported that 25th October sown crop gave higher yield in comparison to 10th November or 25th November sowing. Yaduraju and Ahuja (1997) also observed similar results.

The data further revealed that crop sown at higher seed rate (150 kg ha^{-1}) gave significantly more grain yield compared to crop sown at recommended seed rate

Table 4.14: Effect of different treatments on Seed yield and straw yield (q/ha) of wheat

Treatments	Seed yield (q/ha)	Straw yield (q/ha)
Dates of sowing		
Nov.1	39.27	67.23
Nov.15	36.41	64.71
Nov.30	32.29	62.89
C.D. (0.05)	2.57	6.13
Seed rate (Kg ha^{-1})		
100	38.42	62.73
150	42.29	70.23
C.D. (0.05)	2.43	6.84
Spacing (cm)		
15	41.41	66.23
22.5	39.11	63.39
C.D. (0.05)	1.91	2.72
Herbicide		
Clodinafop (60 g ha^{-1})	45.28	74.23
Unweeded check	29.31	54.27
C.D. (0.05)	2.11	4.17

($100\ kg\ ha^{-1}$) and the increase in the yield was to the tune of 5 per cent. It was observed that under increased crop density achieved by using higher seeding rate, wheat plants were comparatively taller; (Table 4.6) had more LAI (Table 4.11) and more PAR interception (Table 4.12). On the other hand *Avena ludoviciana* was suppressed significantly (Table 4.1) and thereby less competition from *Avena ludoviciana* and there was more number of ear bearing tillers per unit area (Table 4.9) leading to increase in grain yield (Table 4.14) at one and half time ($150\ kg\ ha^{-1}$) the recommended seed rate. Singh (2002) reported that grain yields were significantly higher in crop sown with 150 kg seed rate than that raised with lower seed rate. These findings are also being supported by Parihar and Singh 1995 and Angiras and Sharma 1996.

The data further showed that closed spaced crop (15 cm) resulted in significantly higher grain yield, which was 6 per cent more as compared to normal spacing. Narrow row spacing (15 cm) of wheat due to better distribution of plants over a unit area, tended to intercept relatively more solar radiation at all the crop stages (Table 4.12) which resulted in more number of ear bearing tillers per meter row length

(Table 4.9) and hence, resulted in higher grain yield of crop. Less light interception by plants at wider row might have become a limiting factor in the production of crop biomass and tillers (Table 4.9) and thereby led to less grain yield of wheat. Singh *et al* 2003 also reported that narrow row spacing of 15 cm resulted in significantly higher grain yield of wheat as compared with normal spaced crop of 22.5 cm. The similar results were also reported by Kaur and Bajwa (2001) and Bhullar and Walia (2003).

Further, the closer sowing (15 cm) of wheat produced more dry matter than crop sown in wider 22.5 rows (Table 4.6) and proved superior in smothering *Avena ludoviciana*. More dry matter production of *Avena ludoviciana* plants under normal spaced crop of 22.5 cm (Table 4.3) suppressed the wheat growth in terms of total dry matter accumulation which resulted in lesser PAR interception, which ultimately produced less grain yield (Brar and Singh 1997, Chahal *et al* 2003, Bhullar and Walia 2003).

The post emergence application of clodinofop (60 g ha^{-1}) completely eliminated the competition from *Avena ludoviciana* and thus proved significantly superior to unweeded check and hence registered an increase of 54.48 per cent in grain yield over unweeded check. Chahal *et al* (2003) reported that the treated plots resulted in 53.9 per cent higher grain yield over unweeded check due to selective kill of *Avena ludoviciana*.

The interaction between dates of sowing and seed rate was significant and given in table 4.15. The data revealed that wheat crop sown on 1st November and 15th November had grain yield at par with each other but significantly higher than 30th November sowings at both seed rates. Higher seed rate (150 kg ha^{-1}) produced higher grain yield at all the dates of sowing. 1st date of sowing (1st November) in combination with 150 kg ha^{-1} seed rate produced maximum grain yield.

Straw yield

The data on straw yield (Table 4.14) of wheat under different treatments revealed that 1st November produced significantly higher straw yield as compared to 15th November and 30th November sown crop. Singh *et al* (1997) and Sardana *et al* (2002) also observed that with delay in planting of wheat, straw yield starts to decrease.

Similarly, higher seed rate of 150 kg ha^{-1} produced significantly higher straw yield as compared to 100 kg ha^{-1}.

Table 4.15: Interaction effect of different treatments on grain yield (q ha^{-1}) of wheat

	Date of sowing		
Seed rate	**Nov 1**	**Nov 15**	**Nov 30**
100 kg/ha	41.40	39.40	37.24
150 kg/ha	42.89	40.07	38.21

Interaction CD (0.05) = 1.98

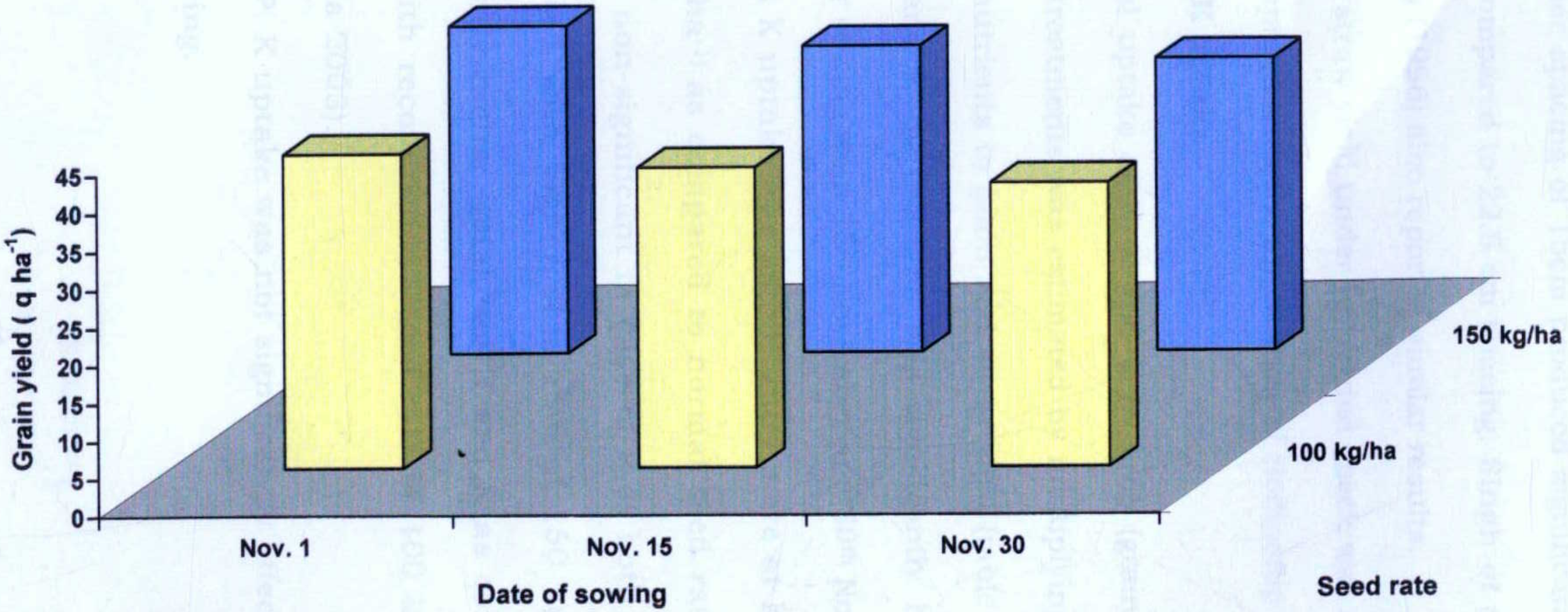


Fig. 4.8 : Interaction effect of different treatments on grain yield of wheat

Closer spacing of 15cm produced significantly higher straw yield as compared to 22.5 cm spacing. Singh *et al* (2003), Singh and Singh (1996) also reported similar results.

The straw yield under unweeded check was significantly less when compared with the application of clodinafop (60 g ha^{-1}).

N, P and K uptake

Total uptake of N, P and K by crop (grain + straw) under different treatments was estimated by multiplying the percentage of these nutrients to grain and straw yield (table 12). The uptake of N, P and K by the crop was significantly higher under 1st November sowing than 15th November and 30th November sowing.

N & K uptake was significantly more at higher seed rate (150 kg ha^{-1}) as compared to normal seed rate (100 kg ha^{-1}) but it is non-significant in case of P at both the seed rates. Crop raised with higher seed rate of 150 kg ha^{-1} recorded significantly higher uptake of N and K as compared to crop raised with recommended seed rate of 100 kg ha^{-1} (Bhullar and Walia 2003).

N, P, K uptake was not significantly affected by different row spacing.

Table 4.16: Effect of different treatments on nutrient uptake of N, P and K by wheat

	Nutrient uptake (kg ha^{-1})		
Treatments	**N**	**P**	**K**
Dates of sowing			
Nov.1	143.2	28.4	149.2
Nov.15	109.4	25.1	124.5
Nov.30	84.5	23.9	119.2
C.D. (0.05)	16.7	1.81	8.25
Seed rate (Kg ha^{-1})			
100	137.4	26.8	128.2
150	140.2	27.2	134.2
C.D. (0.05)	14.21	NS	8.2
Spacing (cm)			
15	123.4	27.8	134.2
22.5	124.7	28.9	132.7
C.D. (0.05)	NS	NS	NS
Herbicide			
Clodinafop (60 g ha^{-1})	143.7	30.8	153.2
Unweeded check	66.2	18.1	102.5
C.D. (0.05)	8.53	5.11	5.48

Significantly more nutrient removal by the crop was observed with the application of clodinafop (60 g ha^{-1}) compared to unweeded check.

CHAPTER-V

SUMMARY

A field investigation entitled "Competitive ability of wheat (*Triticum aestivum* L.) against wild oats (*Avena ludoviciana* Dur.) as influenced by date of sowing, seed rate and spacing" was conducted at the Research Farm of the Department of Agronomy, PAU, Ludhiana during rabi 2006-07. The soil of the experimental field was loamy sand in texture and normal in reaction and in content of soluble salts. The soil tested low in organic carbon and available nitrogen and medium in available phosphorus and potassium. Recommended cultural practices except for treatments under study and plant protection measures were followed throughout the crop growth season. The salient findings of the study are summarised as under:-

Effect of dates of sowing

⇒ The population, plant height and dry matter accumulation of *Avena ludoviciana* reduced greatly under 1st November and 30th November sown crop compared to 15th November sown crop at all the growth stages. The growth and development of *Avena ludoviciana* reduced with delayed sowing.

⇒ The uptake of N,P,K by *Avena ludoviciana* was significantly less in 30th November sown crop as compared to 1st November and 15th November sown crop. This might be due to less dry matter accumulation by weed under 1st and 15th November sown crop.

⇒ The growth characteristics of wheat *viz.* plant height, dry matter accumulation, tiller count, LAI and PARI were significantly greater under 1st November and 15th November sown crop as compared to 30th November sown crop.

⇒ RGR of wheat crop was significantly higher in 30th November sown crop as compared to crop sown on 1st November and 15th November at 60 and 120 DAS. However, 90 DAS RGR was significantly higher in 1st November sown crop than 30th November sown crop but statistically at par with 15th November sown crop.

⇒ Yield contributing characteristics *viz.*, spike length, grains per ear and test weight were significantly higher in 1st November sown crop as compared to 15th and 30th

November sown crop. These characteristics accounted for a significantly higher seed yield in 1st November sown crop as compared to 15th November and 30th November sown crop. Similarly straw yield of the crop and N, P, K uptake by crop were significantly higher in 1st November sown crop as compared to 15th November and 30th November sown crop.

Seed Rate

⇒ Density, plant height, dry matter accumulation and N, P, K uptake of *Avena ludoviciana* was significantly less in crop sown with higher seed rate (150 kg ha^{-1}) as compared to crop sown with recommended seed rate (100 kg ha^{-1}). It is due to more suppressing effect of higher seed rate.

⇒ The growth characteristics of wheat crop i.e. plant height, dry matter accumulation, LAI, tiller count, PAR and RGR were significantly higher in crop sown with higher seed rate as compared to crop sown with recommended seed rate.

⇒ Yield attributes *viz.*, spike length, grains per ear and test weight were significantly higher in crop sown with

⇒ higher seed rate (150 kg ha^{-1}) as compared to crop sown with recommended seed rate (100 kg ha^{-1}). This resulted in significantly higher seed yield in crop sown with higher seed rate. This is due to favourable effect of higher seed rate on yield attributes.

Spacing

⇒ Higher values of density, dry matter accumulation and N, P, K uptake by *Avena ludoviciana* were obtained in crop sown with recommended spacing of 22.5 cm as compared to closer spacing of 15 cm. This due to more space available to the weeds for their establishment in wider row sown crop.

⇒ Plant height of *Avena ludoviciana* and wheat were not significantly effected by differential spacing.

⇒ The growth characteristics of wheat *viz.*, dry matter accumulation tiller count, LAI and PAR were having higher values in crop sown with closer spacing (15 cm) as compared to recommended spacing (22.5 cm).

⇒ Although the crop sown with recommended spacing (22.5 cm) had higher RGR but the differences were non significant.

⇒ Yield attributes of wheat *viz.*, number of grains per ear test weight and seed yield were significantly more in crop sown with closer spacing (15 cm) as compared to crop sown with recommended spacing (22.5 cm). Closer spacing of wheat due to better distribution of plants over a unit area tended to intercept relatively more solar radiation at all crop stages, which resulted in more number of effective tillers per unit area and hence resulted in higher grain yield.

⇒ N, P and K uptake by wheat crop was not significantly effected by various spacings.

⇒ The application of clodinofop (60 g ha^{-1}) provided complete control of *Avena ludoviciana* and registered an increase of 54.48 per cent in grain yield over unweeded check.

⇒ The interactive effect of date of sowing and seed rate showed that at each date of sowing, the crop sown with recommended seed rate i.e. 100 kg ha^{-1} had higher dry matter accumulation of *Avena ludoviciana* than crop sown with higher seed rate (150 kg ha^{-1}). Significantly high dry matter was accumulated by wheat in November

1st sown crop with seed rate of 150 kg ha^{-1}. The interactive effect of date of sowing and seed rate also showed its synergistic effect on seed yield which was maximum in November 1st from crop with a seed rate of 150 kg ha^{-1}.

Conclusions:

It can be concluded that population, biomass, height and N, P and K uptake by *Avena ludoviciana* can be curtailed by providing the competitive advantage in favour of wheat crop through sowing of wheat in the first week of November. However, under late sown conditions use of higher seed rate (150 kg ha^{-1}) helped in smothering the growth of *Avena ludoviciana*.

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Appendix 1. Weekly meteorological data during the crop season (2006-07)

Weekly interwal	Standard week	Temperature (^0C)			Mean Relative Humidity (%)	Sunshine hours	Rainfall (mm)	Total Evapo-ration (mm)
		Max.	Min.	Mean				
29/10/06-4/11/06	44	29.3	15.5	22.4	73	6.2	0.0	14.0
5-11/11/06	45	29.3	15.8	22.5	69	2.8	0.0	12.5
12-18/11/06	46	27.5	13.5	20.0	68	5.4	0.0	15.2
19-25/11/06	47	24.1	11.4	17.7	72	7.9	14.0	14.4
26/11/06-2/12/06	48	22.1	6.6	14.3	64	8.2	0.0	13.7
3-9/12/06	49	19.2	9.6	14.4	78	3.8	6.4	11
10-16/12/06	50	19.3	6.9	12.9	76	5.9	0.0	7.7
17-23/12/06	51	21.7	6.9	14.3	70	6.5	0.0	9.9
24-31/12/06	52	19.4	5.8	12.6	76	7.1	2.3	11.2
1-7/01/07	1	16.1	2.8	9.4	74	7.2	0.0	10.1
8-14/01/07	2	17.7	1.8	9.7	71	7.1	0.0	9.9
15-21/01/07	3	19.2	4.2	11.7	69	7.8	0.0	13.1
22-28/01/07	4	22.8	5.4	14.2	73	7.9	0.0	13.8
29/01/07-4/02/07	5	23.7	9.2	11.4	77	6.5	10.0	14.0
5-11/02/07	6	20.6	12.4	16.5	81	4.1	41.9	12.0
12-18/02/07	7	16.8	9.7	13.2	79	3.8	33.7	7.2
19-25/02/07	8	22.0	8.1	15.0	74	8.8	0.0	14.9
26/02/07-4/03/07	9	21.3	11.3	16.2	77	6.9	9.1	15.6
5-11/03/07	10	24.2	10.3	17.2	69	8.4	3.1	23.1
12-18/03/07	11	22.6	11.2	16.9	75	8.3	34.2	21.6
19-25/03/07	12	28.0	14.4	21.2	66	8.7	4.0	26.8
26/03/07-1/04/07	13	33.2	16.6	24.9	60	10.2	0.0	32.2
2-8/04/07	14	32.5	15.5	24.0	54	11.2	0.0	41.7
9-15/04/07	15	38.0	18.4	28.2	47	11.4	0.0	49.7

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