EFFECT OF SEED RATE AND WEED CONTROL METHOD ON GROWTH AND PRODUCTIVITY OF WHEAT UNDER TILL AND NO-TILL CONDITION

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF SEED RATE AND WEED CONTROL METHOD ON GROWTH AND PRODUCTIVITY OF WHEAT UNDER TILL AND NO-TILL CONDITION"** submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** with major in **Agronomy** and minor in **Soil Science** of Post-Graduate Studies, G. B. Pant University of Agriculture & Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Sanjay Kumar, Id. No. 28870,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

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(R.C. Gautam)
Chairman
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CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Sanjay Kumar, Id. No. 28870,** a candidate for the degree of **DOCTOR OF PHILOSOPHY** with major in **Agronomy** and Minor in **Soil Science** and agree that the thesis entitled **"EFFECT OF SEED RATE AND WEED CONTROL METHOD ON GROWTH AND PRODUCTIVITY OF WHEAT UNDER TILL AND NO-TILL CONDITION"** may be submitted in partial fulfilment of the requirements for the degree.

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INTRODUCTION

1. INTRODUCTION

Spread and intensity of cropping of an area depends on its soil, climate, social and economical conditions of farmers. In India wheat is the most important cereal crop next to rice, grown under diverse agro-climatic conditions, covering 25.9 million hectare area, contributing 71.9 million tonnes production with 2776 kg ha^{-1} productivity (The Hindu, Survey of Indian Agriculture, 2003). About 90 per cent of the total wheat production in the country is contributed from U.P., Punjab, Haryana, M.P. and Rajasthan.

Inspite of high claims for development of irrigation system a large share of cultivated area is still rainfed. Therefore crop usually faces droughts resulting poor field preparation, poor germination ineffective weed control, and reduction in net sown area. In these situations where reserve soil moisture is often sub-optimal, early sowing is only the alternative left for good crop establishment.

Crop husbandry is becoming day by day non-beneficiary due to increasing cost of inputs i.e. machines, labour, fuel and agro-chemicals. Beside injudicious use of inputs has not only raised the production cost but also polluted the environment. So much so drinking water is not escaped from the ill effects of indiscriminate use of agro-chemicals. In order to meet the projected demand of 109 mt by 2020 AD (Gautam, 2001) present productivity of wheat has to be raised to the level of 4.29 tonnes ha^{-1}. A wide yield gap (1.5 to 2.0 tonnes ha^{-1}) between field demonstrations and farmers yield indicates the scope for substantial increase in wheat yield.. In the years to came there will be a steep increase in the energy demand for agriculture. Therefore, there is need to optimise energy usages and minimise production cost by optimising cultivation practices i.e. tillage, seeding and weed control etc.

Wheat is traditionally believed to require fine tilth for good yields. Tillage is a critical input for crop production in general and for wheat production in particular. No doubt tillage provides good tilth for the growth and development of crop plants but excessive tillage is not only wastage of time but costly, harmful to soil health and creates environmental hazards. Increasing cost of pre-sowing tillage operations for wheat is declining the profitability day by day.

No-till system permits growing of more crops in a crop sequence despite the short turn around period available in intensive cropping system (Sharma and Prasad, 2002). In addition to saving in tillage costs it has potential to give higher productivity also for delayed sowing of wheat. No tillage can minimise the erosion, energy and labour requirement. No-tillage not only helps in achieving potential production, stability and sustainability but also maintain soil productivity and environmental quality.

Optimum plant population is major component of crop productivity as it has got direct relationship with crop yield. Though the significance of plant population is much more in non-tillering crops but in tillering type crops also population plays a key role. Seed rate is decided on the basis of several factors i.e. seed size, tillering ability, germination percentage, sowing time, soil moisture content, tillage system, time and method of sowing. But seed rate plays important role in determining crop stand and consequently the yield. Generally for no-tillage higher seed rate is required to minimise the yield loss due to poor plant stand and more weed infestation.

Weeds the opportunist plants numbering 250000 species in the world, about 250 are found to cause serious damage to the crop community and have a global ubiquitous influence on crop production. Because these are well adapted and highly competitive with crop plants for nutrients, moisture, space, sunlight. Weeds also interfere in agricultural operations and ultimately reduce the economic produce and its quality. Generally, an increase in one kilogram weed dry weight corresponds to reduction in one kilogram of crop dry weight. Weeds take nearly one third of fertilizer nutrients applied to the crop in the first three weeks of growth. From one hectare area of soil, weeds are estimated to remove about 1250 tonnes of water in a season. Under dry land conditions water is much valuable for successful crop production. According to recent estimates weeds cause an annual loss of Rs.2000/- crores to Indian agriculture which is far more than the total losses caused by insects, pests and diseases (Kumar and Jagannathan, 2003). In case of wheat crop, yield loss ranges between 6.3% to 34.8% due to weeds only. A reduction in weed population under no-tillage may be due to the reduction in soil disturbance which might inhibit germination of weed seeds from lower depths.

Similarly weed control through herbicides is also a prime requirement of no-tillage. High input technology adopted for wheat cultivation has created favourable conditions for luxuriant growth of weeds throughout wheat growing areas in the country.

Among herbicides, the use of isoproturon has been recommended for commercial use by the farmers to control weeds in wheat crop. *P. minor* in some parts of Haryana and Punjab has developed resistance of isoproturon (Malik and Singh, 1993; Walia *et al.*, 1997). Manual weed control is a common practice with most of the farmers. But schedules of hand weeding have become not only difficult but almost impossible to perform due to higher cost, time taking and scarcity of labourers. Hence, use of herbicides to control the weeds has become inevitable (Gautam, 2001).

Since no single practice is capable of solving the problems indicated above but there is possibility of having more effective impact of integration of different factors to optimise the use of inputs.

Keeping above facts in view, present field experiment was planned with following objectives to study the effect of tillage, seed rate and weed control method on:

(i) growth, development and productivity of wheat

(ii) occurrence, growth and density of weeds in association with wheat and

(iii) efficiency and economics of weed control.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Attempt has been made here to review the available information on effect of tillage, seed rate and weed control method on wheat and weeds.

2.1 Effect of tillage on

2.1.1 Growth and development

2.1.1.1 Germination and plant population

Skorda *et al.* (1997) concluded that plant density was not affected due to reduced tillage system and direct drilling after paraquat spray. Rath (1999) found poor plant population under no-till as compared to till condition. Asefa *et al.* (2000) noted that minimum tillage did reduce seedling density at emergence in comparison to tillage. Dixit *et al.* (2003) reported that germination was more in no-till than till system.

2.1.1.2 Plant height

Singh *et al.* (1998) reported lower plant height under no-till as compared to conventional till but differences were not significant. Rath (1999) concluded that no-till resulted shorter plants than conventional till condition. Pandey *et al.* (2000) noted that plant height was not significantly affected by tillage practices (till and no-till). While Das and Verma (2003) found maximum plant height in no-till condition with mulching, which was significantly more than that of conventional till and sole no-till.

2.1.1.3 Leaf area index

Singh (2001) observed significantly more leaf area under conventional than that of no-till system at all the growth intervals. While Chahal *et al.* (2003) reported that leaf area index at 120 DAS was significantly more under deep tillage as compared to conventional and no-till system. However, the differences between conventional and no-tillage were not significant.

2.1.1.4 Plant dry weight

Arshad *et al.* (1994) observed consistently higher dry matter due to reduced tillage as compared with conventional or no-tillage, although the differences were not significant with no-tillage. However, over the season, tillage system ranked as reduced tillage > no-tillage > conventional tillage. David *et al.* (1999) noted no-tillage as major determinant of increased crop growth rate and dry matter accumulation. On contrary Bellido *et al.* (2000) concluded that dry matter was significantly greater under conventional than under no-tillage. Das and Verma (2003) found highest dry matter under no-tillage with mulching, which was significantly more than conventional and no-tillage.

2.1.1.5 Root growth

Pearson *et al.* (1991) reported that total root length during the seeding stage was lower in minimum tillage than in the conventional and the differences were not seen later. While, Merrill *et al.* (1996) reported more root growth in no-tillage than the conventional tillage. Hajabbasi (2001) reported that average root length density for conventional tillage was significantly higher than no-tillage. Aggarwal and Sharma (2002) observed that root length density of wheat in 0-25 cm soil layer under deep tillage was 3-6 fold more than under normal and minimum tillage. Sharma (2003) reported that under conventional tillage root length density was greater than zero tillage in 0-10 cm and 10-20 cm soil layers.

Whereas, Ishaq *et al.* (2003) fond that the tillage method had no significant effect on the root length density at 0-15 m depth. However, greater root length density was obtained for minimum tillage in the subsoil.

2.1.1.6 Days taken to heading

Pandey *et al.* (2000) noted that number of days taken to 50 per cent heading was not affected by conventional or no-tillage. While Singh (2001) observed that heading was significantly affected by tillage system and more days were taken to heading under no-tillage as compared to conventional.

2.1.1.7 Days taken to maturity

Pandey *et al.* (2000) reported that more number of days to maturity was observed under no-tillage over conventional. However, Singh (2001) noted that maturity period was not affected by tillage practices.

2.1.2 Yield and yield attributes

2.1.2.1 Number of spikes

Singh *et al.* (1998) reported that the ears m^{-2} was not affected significantly due to conventional and no-till. Tripathi *et al.* (1999) observed that during first year ears m^{-2} was significantly higher under conventional tillage than in no-tillage and reduced tillage but during second year reduced tillage gave the significantly higher ears m^{-2} than conventional tillage and no-tillage. Bellido *et al.* (2000) concluded that the number of heads m^{-2} was greater with conventional tillage than no-tillage. Pandey *et al.* (2000) noted that effective tillers m^{-2} were significantly higher under conventional than in no-tillage. Srivastava *et al.* (2002) reported that conventional tillage operations were superior to no-tillage as regards to effective tillers m^{-1} row length.

On contrary, Tripathi and Chauhan (2001) noted that under no-tillage spikes m^{-2} were significantly higher than that of conventional tillage. Dixit *et al.* (2003) found that effective count was more in no-till system compared to that of conventional tillage system.

2.1.2.2 Spike length

Singh *et al.* (1998) reported that ear length was higher under conventional tillage as compared to no-tillage system but the difference was not significant. Similar finding were also reported by Singh (2001).

2.1.2.3 Number of spikelets spike^{-1}

Singh (2001) observed that the fertile, sterile and total spikelets spike^{-1} did not differ significantly due to conventional and no-tillage system. While Srivastava *et al.* (2002) reported that conventional tillage was superior to no-tillage as regards to spikelets spike^{-1}.

2.1.2.4 Number of grains spike^{-1}

Singh *et al.* (1998) reported that grains ear^{-1} was not affected significantly due to conventional and no-tillage. Tripathi *et al.* (1999) also observed that tillage system did not have consist effect on grains spike^{-1}. Pandey *et al.* (2000) noted that the grain ear^{-1} was not significantly affected by no-till and conventional till practice. But Tripathi and Chauhan (2001) observed that under no-till system grains spike^{-1} were significantly higher than conventional tillage.

2.1.2.5 1000-grain weight

Singh *et al.* (1998) reported that 1000-grain weight was significantly higher under conventional than no-tillage system. However, Tripathi *et al.* (1999) found that the 1000-grain weight was significantly higher under no-tillage than conventional and reduced tillage system. Tripathi and Chauhan (2001) also observed significantly higher 1000-grain weight under no-tillage as compared to conventional tillage.

While, Pandey *et al.* (2000) noted that the 1000-grain weight was not significantly affected by no-tillage and conventional tillage.

2.1.2.6 Grain yield

Halvorson *et al.* (1999) noted that grain yield was higher with no-tillage and minimum tillage than conventional tillage, but tillage effects on grain yield varied among years. Tripathi and Chauhan (2000) reported maximum grain yield of wheat with no-tillage followed by conventional tillage. Reinhard *et al.*

(2001) observed that no-tillage resulted slightly higher average yield than conventional tillage. Tripathi and Chauhan (2001) concluded that no-tillage recorded significantly 13.2 per cent higher yield as compared to conventional tillage. Singh *et al.* (2002) reported that yield in no-till plots was 4 per cent higher over conventionally till plots. Dixit *et al.* (2003) reported that grain yield of wheat under no-till system was 17.09 per cent higher as compared to conventional method. Pandey *et al.* (2003) found that no-till technology gave 4.8 per cent significantly higher yield as compared to conventional technology. Singh (2004) observed that no-tillage produced significantly higher grain yield as compared to conventional tillage. On the same date of sowing yield was at par or slightly higher under no-tillage (Singh and Singh, 2004).

While Rath (1999) reported that conventional method resulted more grain yield than that of no-till. Singh and Gangwar (1999) observed that grain yield was 27 per cent more with conventional as compared to no-till operation. Pandey *et al.* (2000) noted that conventional tillage produced 10-12.3 per cent higher grain yield over no-tillage. Workayehu and Workayehu (2000) found that the yield from two and three ploughing were 42 and 18 per cent lower, respectively, than four ploughings. The results showed that repeated tillage increased the grain yield significantly over no-tillage. Das and Verma (2003) reported that no-tillage with mulching resulted distinct improvement in grain yield as compared to no-tillage and it was well comparable with conventional tillage. However conventional tillage produced more grain yield than no-tillage.

On the other hand, Asefa *et al.* (2000) concluded that minimum tillage had no effect on yield and yield components. William F. Schillinger (2001) observed that different tillage practices (i.e. conventional, minimum and delayed minimum) did not affect the grain yield.

2.1.2.7 Straw yield

Tripathi *et al.* (1999) reported that higher straw yield was noted under conventional tillage as compared to no-tillage. Das and Verma (2003) also noted more straw yield with conventional tillage than no-tillage. While, Tripathi and Chauhan (2001) recorded significantly higher straw yield under zero-tillage as compared to conventional tillage. Dixit *et al.* (2003) reported that straw yield under no-tillage was higher than conventional tillage.

But Singh *et al.* (1998) noted that straw yield was not affected significantly due to no-tillage and conventional tillage system. Chauhan *et al.* (2003) concluded that straw yield between zero and conventional drill was almost same and the lowest was obtained in the broadcasting.

2.1.3 Weeds

Martin and Felton (1993) observed that tillage affected vertical distribution of wild oat seeds in soil and approximately 80 percent of seeds were in top 5 cm soil. Skorda *et al.* (1997) concluded that on no-till soil, less annual weeds were found than tilled soil, but grassy weeds caused difficulties. Singh *et al.* (1998) reported that population of monocot weeds was significantly more in no-till plots than conventionally till plots.

This also resulted significantly more weeds in no-till plots than in conventionally till plots. The major weeds were *Cynodon dactylon* (L.) Pers., *Phalaris minor* (Retz.) Pers, *Avena ludoviciana* L.; *Melilotus* sp.; *Anagallis sp.*, *Rumex* sp.; and *Cirsium arvense* (L.) Scop. *Asefa et al.* (2000) found that the density of weed species *Bromus pectinatus* and *Galinosoga parviflora* increased under minimum tillage. Density of weeds was significantly affected by the tillage system (Streit *et al.*, 2000). Workayehu and Workayehu (2000) reported that repeated tillage (one, two, three and four ploughing) reduced weed infestation and increased the grain yield. Tuesca *et al.* (2001) concluded that annual broad leaved weeds showed higher population in conventional tillage, and grassy annuals and perennial species showed an erratic response to tillage systems. Eighty six percent farmers reported less infestation of weeds mainly *Phalaris minor* in no-till fields compared to conventional till fields (NATP, 1999-2003). Dixit *et al.* (2003) observed that under no-tillage system weed intensity was lower than conventional tillage system. Das and Verma (2003) observed significant decrease in total weed population and dry weight under conventional tillage and zero tillage with mulching as compared to sole zero-tillage.

2.1.4 Nutrient content and uptake

The crop sown under conventional tillage observed higher concentration of nutrients i.e. N, P, K, Zn and Fe in grain and straw as compared to the crop sown without any preparatory tillage (Rath, 1999). Asefa *et al.* (2000) concluded that conventional tillage increased straw nitrogen content in comparison to minimum tillage. Mozafar *et al.* (2000) reported that the concentration of P, K, Mn and Zn were higher in the tops of plants under no-tillage than under conventional tillage at most sampling dates. In contrast, at the early stage of growth, the concentration of Ca in wheat was higher in conventional tillage than no-tillage.

Arshad *et al.* (1994) observed that the concentration of total nitrogen in plants and grains of wheat was not significantly affected by tillage. Ishaq *et al.* (2003) also observed that concentration of N and P in grain was not affected by conventional and no-tillage.

Rath (1999) concluded that crop sown with conventional tillage observed higher uptake of nutrients i.e. N, P, K, Zn and Fe in grain and straw as well as their total uptake by the crop as compared to the crop sown without any tillage operations. Asefa *et al.* (2000) reported that conventional tillage increased nitrogen uptake by straw in comparison to reduce tillage. While, Aggarwal and Sharma (2002) noted that N-uptake by wheat roots was not influenced by tillage practices (deep, normal, minimum and shallow-minimum).

2.1.5 Economics

Tripathi *et al.* (1999) noted that the cost of cultivation in conventional tillage was around Rs.7200 ha^{-1}, whereas in zero-tillage it was only Rs.6050 ha^{-1}. Kosutic *et al.* (2001) reported that conventional tillage system consumed maximum amount of energy, while no-till system required 85.1 per cent less energy ha^{-1}. The production cost was higher under conventional (Rs.8265) as compared to no-tillage (Rs.4394) (NATP, 1999-2003). Dixit *et al.* (2003) noted that total energy requirements and cost of operations were higher in conventional than no-tillage system. The energy required for no-tillage and conventional tillage were 9.15 and 54.33 MJ q^{-1} of grain produced, respectively. Pandey *et al.* (2003) noted that the average cost of production reduced from Rs.3810 per tonne with conventional to Rs. 2750 per tonne under zero-till technology.

Verma and Srivastava (1989) reported that net returns was higher in optimum tilled plots (Rs.2989 ha^{-1}) as compared to no-tillage (Rs.2878 ha^{-1}). Das and Verma (2003) reported that conventional tillage gave higher gross return, net return and net return $rupee^{-1}$ invested as compared to no-tillage.

Chauhan *et al.* (2003) observed that among zero, rotary, conventional tillage (drill) and broadcasting, highest net returns and benefit : cost ratio were observed in rotary tillage, followed by zero-tillage and the lowest in conventional broadcasting sowing. Pandey *et al.* (2003) found that no-till technology was more profitable than conventional technology. With about only 5 per cent yield gains but 28 per cent reduction in the average cost of production with no-tillage, the net return increased from Rs.11120 to Rs.15472 ha^{-1}. All these changes are significantly different under the two tillage practices.

2.2 Effect of seed rate on

2.2.1 Growth and development

2.2.1.1 Germination and plant population

Maximum germination and number of shoot m^{-2} were recorded under 150 kg ha^{-1} over 100 kg ha^{-1} seed rate (Mishra, 1996). Upadhyay and Tiwari (1996) observed significant increase in plant population m^{-2} under 150 kg over 100 kg ha^{-1} seed rate. Turley (1999) reported that establishment was approximately 62 per cent at 80 and 200 seeds m^{-2} and 48 per cent at 400 seeds m^{-2}. But average plant population was 50, 125 and 193 plants m^{-2}, respectively. Wood *et al.* (2003) found that plant population increased upto the highest seed rate.

2.2.1.2 Plant height

Plant height did not differ significantly due to different seed rates (Singh and Rafey, 1998 and Kumpawat, 1998). Biswas *et al.* (1999) reported that sowing with lower seed rate (80 kg ha^{-1}) resulted taller plants over higher seed rate (120 to 200 kg ha^{-1}). Singh *et al.* (2002) reported that plant height decreased with increasing seeding rates (100 to 125 and 150 kg ha^{-1}). While, Arif *et al.* (2002) reported maximum plant height at maximum seed rate.

2.2.1.3 Leaf area index

Mishra (1996) concluded that the number of physiologically active leaves and leaf area reduced with increasing seed rate. Similarly, Singh *et al.*

(2002) observed that number of leaves plant^{-1} decreased with increasing seeding rates. Singh *et al.* (2003) reported highest leaf area index at higher (150 kg ha^{-1}) over lower seed rate.

2.2.1.4 Plant dry weight

Mishra (1996) observed higher dry matter accumulation under higher seed rate. Singh *et al.* (1999) concluded that increasing seed rate from 100 to 150 and 200 kg ha^{-1} resulted increase in dry matter accumulation. Kumar *et al.* (2002) reported that dry matter accumulation increased significantly with increasing seed rate from 90 to 180 kg ha^{-1}.

2.2.1.5 Days taken heading

Srivastava *et al.* (1996) reported that number of days taken to 50 per cent heading did not differ significantly due to different seed rates.

2.2.1.6 Days taken to maturity

Srivastava *et al.* (1996) noted that number of days taken to maturity did not differ significantly due to different seed rates.

2.2.2 Yield and yield attributes

2.2.2.1 Number of spikes

Sharma and Malik (1993) reported non-significant differences in effective shoots m^{-1} row length due to different seed rates. Similar results was also noted by Singh *et al.* (2000). While, Singh *et al.* (2002) observed that number of effective tillers increased significantly with a corresponding increase in seed rate. Sen *et al.* (2003) reported that number of productive tillers increased significantly with the increase in seed rate from 125 to 150 and 175 kg ha^{-1}. But Upadhyay and Tiwari (1996) noted that with increasing seed rate increased the number of effective shoots m^{-1} row length. Similar results were also obtained by Mishra (1996) and Biswas *et al.* (1999). Srivastava *et al.* (1996) reported that higher seed rate of 150 kg ha^{-1} resulted maximum spikes m^{-1} row length over normal seed rate. Arif *et al.* (2002) were also of similar opinion.

2.2.2.2 Spike length

Paul (1992) reported that spike length was non-significantly affected by seed rate. Similar results were obtained by Sharma and Malik (1993) and Singh and Rafey (1998). Singh *et al.* (2000) concluded that length of spike was statistically at par amongst different seed rates.

While, Kumpawat (1998) observed that there was significant decrease in spike length with increasing seed rate. Azad *et al.* (1998) reported decrease in spike length with increasing seed rate from 125 to 200 kg ha^{-1}. Similar results were also reported by Singh *et al.* (1999). Singh *et al.* (2002) reported that spike length decreased with increasing seed rate from 100 to 125 and 200 kg ha^{-1}.

However, Singh *et al.* (1993) reported that spike length increased significantly with increasing seed rate. Biswas *et al.* (1999) reported that lower seed rate (80 kg ha^{-1}) resulted highest ear length.

2.2.2.3 Number of spikelets spike^{-1}

Sharma and Malik (1993) noted that the number of fertile spikelets spike^{-1} was not affected significantly due to seed rates. Upadhyay and Tiwari (1996) reported that fertile spikelets spike^{-1} increased at higher seed rate. Mishra (1996) found that number of fertile spikelets spike^{-1} decreased with increasing seed rate. Pandey *et al.* (1999) concluded that increasing seed rate had no-significant effect on fertile spikelets spike^{-1}. Biswas *et al.* (1999) observed that lower seed rate (80 kg ha^{-1}) gave the highest number of spikelets spike^{-1} over higher seed rates (120 to 200 kg ha^{-1}).

2.2.2.4 Number of grains spike^{-1}

Upadhyay and Tiwari (1996) reported that number of grains spike^{-1} decreased with increasing seed rates. Similar results were obtained by Mishra (1996), Singh *et al.* (2002) and Arif *et al.* (2002).

Ahuja *et al.* (1996) reported that seed rate did not have significant effect on number of grains spike^{-1}. Similar results were also noted by Singh and Rafey (1998) and Pandey *et al.* (1999). Singh *et al.* (2002) concluded that number of grains spike^{-1} was statistically at par amongst 150 and 200 kg ha^{-1} seed rate. While, Biswas *et al.* (1999) reported that lower seed rate (80 kg ha^{-1}) gave the highest number of grains spike^{-1} over highest seed rate upto 200 kg ha^{-1}. Similar results was obtained by Wood *et al.* (2003).

2.2.2.5 Grain weight spike^{-1}

Ruegger *et al.* (1993) observed that lower seed rate increased grain weight over normal seed rate. While, Upadhyay and Tiwari (1996) observed that grain weight spike^{-1} increased with increasing seed rate. Similarly, Azad *et al.* (1998) reported highest grain weight ear^{-1} at 125 kg seed ha^{-1}.

Singh and Uttam (1993) found significant decrease in grain weight spike^{-1} at higher seed rate. Ahuja *et al.* (1996) reported that grain weight spike^{-1} decreased with increase in seed rate. Same results were observed by Mishra (1996), Singh and Rafey (1998) and Singh *et al.* (2002).

2.2.2.6 1000-grain weight

Ahuja *et al.* (1996) observed that test weight was not affected significantly due to seed rate. Similar trend was observed by Srivastava *et al.* (1996), Singh and Rafey (1998) and Pandey *et al.* (1999). Gooding *et al.* (2002) noted that effect of seed rate on 1000-grain weight was small and inconsistent. Singh *et al.* (2000) concluded that test weight was statistically at par amongst different seed rates.

Srivastava *et al.* (1996) found that higher 1000-grain weight at higher seed rate (150 kg ha^{-1}) over normal seed rate (100 kg ha^{-1}). Azimzadeh and Koocheki (1999) reported that increasing seed rate increased thousand grain weight.

On contrary, Biswas *et al.* (1999) reported that lower seed rate (80 kg ha^{-1}) gave highest 1000-grain weight over higher seed rate (120 to 160 and 200 kg ha^{-1}). Similar results were obtained by Mishra (1996), Arif *et al.* (2002) and Wood *et al.* (2003).

2.2.2.7 Biological yield

Gooding *et al.* (2002) found that above ground biomass followed similar asymptotic increase with increased seed rate. Kumar *et al.* (2002) reported that biological yield enhanced significantly with increasing seed rate from normal to high seed rate (180 kg ha^{-1}).

2.2.2.8 Grain yield

Singh and Uttam (1997) reported highest mean grain yield with 100 kg seed ha^{-1} over 75 and 125 kg ha^{-1}. Gaffer *et al.* (1997) reported that amongst different seed rates (100 to 175 kg ha^{-1}), highest grain yield was obtained with 125 kg ha^{-1} seed rate.

Christensen (1994) noted increased grain yield with increased seed rate. Srivastava *et al.* (1994) observed higher grain yield at higher seed rate (120 kg ha^{-1}). Parihar *et al.* (1995) reported that normal seed rate resulted higher grain yield than lower seed rate. Panwar *et al.* (1995) noted that highest grain yield was obtained with highest seed rate (175 kg ha^{-1}) as compared with normal seed rate. Similar trend was also found by Sen *et al.* (2003). Das (1996) reported that increasing seed rates from normal to higher upto 150 kg ha^{-1} resulted increase in grain yield. Similar results were also observed by Upadhyay and Tiwari (1996), Jena and Behra (1998), Shaukat *et al.* (1999), Bairwa *et al.* (2000) and Arif *et al.* (2002). Azimzadeh and Kooeheki (1999) reported that increasing seed rate (120 kg ha^{-1}) increased grain yield, but the highest seed rate (160 kg ha^{-1}) reduced grain yield. Raslon and Fogelfors (2003) concluded that grain yield increased with increasing seed rate (47 kg ha^{-1} to 187 kg ha^{-1}). Gooding *et al.* (2002) reported that grain yield generally followed similar asymptotic increase with increasing seed rate and grain yield followed parabolic response to seed rate with apparent reduction in yield at very high seed rate.

Kumpawat (1998) reported that grain yield increased significantly upto 150 kg seed ha^{-1} and further increase in seed rate did not have consistent effect. Similar results were also noted by Pandey *et al.* (1999), Tripathi and Chauhan (2000). Thakur *et al.* (1999) observed that 200 kg ha^{-1} seed rate resulted significantly higher grain yield than 150 and 100 kg seed ha^{-1}. Kushwaha *et al.* (2002) concluded that grain yield increased significantly with each successive increase in seed rate from 100 to 150 kg ha^{-1}.

However, Ahuja *et al.* (1996) observed that yield was not affected significantly due to seed rates. Similar result were also obtained by Srivastava *et al.* (1996), Singh and Rafey (1998). Biswas *et al.* (1999) noted highest grain yield with normal seed rate over highest seed rate (200 kg ha^{-1}). Similar results were also obtained by Wood *et al.* (2003). Singh *et al.* (2002) reported that grain yield decreased with increasing seed rate (100 kg to 150 kg ha^{-1}).

2.2.2.9 Straw yield

Srivastava *et al.* (1996) observed more straw yield with higher seed rate

(150 kg ha^{-1}) than normal seed rates (100 and 125 kg ha^{-1}). Similar finding were reported by Azimzadeh and Koocheki (1999) and Bairwa *et al.* (2000). Thakur *et al.* (1996) noted maximum straw yield at highest seed rate (200 kg ha^{-1}) as compared to 150 and 175 kg ha^{-1} seed rate. Sen *et al.* (2003) also noted highest straw yield with higher seed rate.

Upadhyaya and Tiwari (1996) reported significant increase in straw yield due to increase in seed rates from normal to higher. Similar findings were also noted by Azad *et al.* (1998), Singh *et al.* (1999), Pandey *et al.* (1999) and Kushwaha *et al.* (2002). Thakur *et al.* (1999) noted significantly higher straw yield at highest seed rate (200 kg ha^{-1}). Similar results were also reported by Kumpawat (1998).

2.2.2.10 Harvest index

Sharma and Malik (1993) reported non-significant effect of seed rate on harvest index. Upadhyay and Tiwari (1996) were also the similar opinion. However, Thakur *et al.* (1999) reported significantly higher harvest index at higher seed rate (150 kg ha^{-1}) than at 200 kg ha^{-1}.

2.2.3 Weeds

2.2.3.1 Weed density

Korres and Froud-Williams (1997) concluded that various seeding rates significantly affected weed suppression of a naturally occurring weed infestation. Jena and Behra (1998) reported that weed density at harvest was higher with normal seed rate (100 kg ha^{-1}). Korres and Froud-Williams (2002) reported that manipulation of seed rate was a more reliable factor than cultivar selection for enhancement of weed suppression. Crop densities between 125 and 270 plant m^{-2} were found to alter adequate weed suppression. Roslon and Fogelfors (2003) reported that increasing seed rate (47 to 187 kg ha^{-1}) reduced the population of perennial weeds by 40-70 per cent.

2.2.3.2 Weed dry weight

Christensen (1994) reported reduction in weed dry matter due to increased seed rate. Panwar *et al.* (1995) observed decrease in weed dry weight with increasing seed rate at 90 DAS in control. Christensen and Rasmussen (1996) reported that seed rates lower than 300 seeds m^{-2} resulted highest weed dry matter. Gaffer *et al.* (1997) reported that weed dry weight decreased with increasing seed rate from normal to higher. Jena and Behra (1998) reported that biomass at harvest was higher with normal seed rate. Singh *et al.* (2000) observed lowest weed dry weight under highest seed rate. Roslon and Fogelfors (2003) reported that the total biomass of weeds was 66 per cent lower at the highest seed rate (187 kg ha^{-1}) as compared to lowest seed rate (47 kg ha^{-1}).

2.2.4 Nutrient content and uptake

Singh *et al.* (1987) reported that increasing seed rate decreased grain N-content. Similar finding were observed by Singh *et al.* (1988). Greenwood *et al.* (1987) reported that the percentage nitrogen in plants decreased with increasing plant population. Gooding *et al.* (2002) reported that grain nitrogen and protein content declined with increase in seed rate. N-concentration in grain and straw was higher at 125 kg ha^{-1} than at 150 kg ha^{-1} seed rate. Biswas *et al.* (1999) found that grain protein content was highest with 120 kg seed ha^{-1} as compared to lower and highest seed rate.

Similarly, P-content in grain was recorded higher under seed rate of 125 kg ha^{-1} than 150 kg ha^{-1} (Mishra, 1996).

Johri *et al.* (1992) found that higher seed rate resulted in higher N, P, K uptake by the crop than normal seed rate. Pandey *et al.* (1999) concluded that seed rate had no-effect on nutrient uptake (N, P and K) by the crop. However, Singh *et al.* (1987) reported that increasing seed rate increased N-uptake in grain + straw. Similar results were noted by Singh *et al.* (1988). Similarly, Bairwa *et al.* (2000) reported that N-uptake was higher with higher seed rate (150 kg ha^{-1}) than normal seed rate (100 kg ha^{-1}). Similar findings were observed by Reddi and Patil (2003). Uptake of N in grain was higher at normal seed rate (125 kg ha^{-1}) than at higher seed rate (150 kg ha^{-1}) (Mishra, 1996). Kaur *et al.* (2002) reported that normal seed rate (100 kg ha^{-1}) increased the N-uptake of wheat over lower and higher seed rate (67 and 150 kg ha^{-1}).

Mishra (1996) concluded the uptake of P in grain was higher under seed rate of 125 kg ha^{-1} than higher seed rate (150 kg ha^{-1}). While Bairwa *et al.* (2000) observed that P-uptake was better with higher seed rate of 150 kg ha^{-1} than normal seed rate of 100 and 125 kg ha^{-1}. On contrary, Kaur *et al.* (2002) reported that P-uptake was higher with normal seed rate (100 kg ha^{-1}) than at lower and higher seed rate. Bairwa *et al.* (2000) reported that K-uptake was higher with higher seed rate (150 kg ha^{-1}) compared at normal seed rate (100 kg ha^{-1}). Whereas, Kaur *et al.* (2002) reported that K-uptake was higher with normal seed rate (100 kg ha^{-1}) than lower and higher seed rate.

Johri *et al.* (1992) found that higher seed rate decreased the N, P and K removal by grasses, broad leaved weeds and by sedges, compared with normal sowing rate.

2.2.5 Economics

Thakur *et al.* (1996) observed that highest seed rate (200 kg ha^{-1}) gave highest net return over lower seed rate (150 and 175 kg ha^{-1}). Christensen and Rasmussen (1996) noted highest net return including the cost of seeds at 450 seeds m^{-2}. Pandey *et al.* (1999) concluded that net return and net return $rupee^{-1}$ invested increased significantly upto 150 kg ha^{-1} seed rate and further increase in seed rate failed to produce any significant effect on net return and net return $rupee^{-1}$ invested. Bairwa *et al.* (2000) reported higher net return with higher seed rate (150 kg ha^{-1}) than normal seed rate. Kumar *et al.* (2002) reported that cost of cultivation, gross and net returns and benefit : cost ratio were highest with 100 kg seed rate over reduced seed rate.

Singh *et al.* (2000) observed that highest seed rate (200 kg ha^{-1}) had significantly higher return over lower seeds (100 and 150 kg ha^{-1}). Kushwaha *et al.* (2002) reported that net return and cost : benefit ratio increased significantly with each successive increase in seed rate (100 to 150 kg ha^{-1}). Karim *et al.*

(1998) observed that among different seed rates (100 to 200 kg ha^{-1}), the highest benefit : cost ratio was noted with 120 kg ha^{-1} seed rate. Wood *et al.* (2003) reported that among varying seed rates highest gross margin was found at the lowest seed rate of 250 seed m^{-2}. Thakur *et al.* (1999) concluded that both net return and net return rupee^{-1} investment were at par with different seed rates.

2.3 Effect of weed control method on

2.3.1 Growth and development

2.3.1.1 Plant population

Singh (2001) concluded that shoot count m^{-2} reduced significantly under weedy check as compared to herbicidal treatments. Pal (2002) observed that shoot count m^{-2} was significantly higher under 1.0 kg ha^{-1} isoproturon as compared to weedy check at al the growth stages of crop.

2.3.1.2 Plant height

Singh (2001) noted that plant height under weedy plots increased significantly over herbicide treated plots at advance stages. Singh and Saha (2001) observed that plant height was higher under hand weeding at 20 and 40 DAS followed by hand weeding + hoeing at 20 DAS, hand weeding at 20 DAS, isoproturon 1.5 kg ha^{-1} and was lowest under weedy check. Pal (2002) noted significantly higher plant height under weed-free, followed by isoproturon @ 1.0 kg ai ha^{-1} over weedy plots at all the growth stages. Pandey and Verma (2002) reported that all the weed control treatments caused significant increase in plant height as compared to weedy check. Hand weeding resulted maximum increase in height and was statistically superior to isoproturon @ 1.0 kg ai ha^{-1}. Significant increase in plant height was observed under isoproturon @ 1.0 kg ha^{-1}, 30 DAS in comparison to weedy (Das and Verma, 2003).

2.3.1.3 Plant dry weight

Dhawan (1995) observed that 1.0 kg ha^{-1} isoproturon at two leaf stage of wheat, decreased dry matter accumulation per plant by 10 per cent. Singh (2001) noted that plant dry weight reduced significantly under weedy check as compared to herbicidal treatment. Das and Verma (2003) observed that isoproturon @ 1.0 kg ha^{-1} at 30 DAS resulted significantly higher dry matter as compared to unweeded control. Aggarwal *et al.* (2003) reported that crop dry weight was higher under isoproturon @ 0.94 kg ha^{-1} treated plots than the weedy.

2.3.1.4 Leaf area index

Singh (2001) observed that leaf area index reduced significantly under weedy check than that of herbicidal treatments at advanced stages of crop growth. Pal (2002) reported significantly higher leaf area index under weed free followed by isoproturon @ 1.0 kg ai ha^{-1} treated plots than weedy plots.

2.3.2 Yield and yield attributes

2.3.2.1 Number of spikes

Saini and Singh (2001) reported that number of effective tillers m^{-1} row length was significantly higher under isoproturon @ 1.5 kg ha^{-1} as well as hand weeding, 40 and 70 DAS as compared to weedy check. Singh and Saha (2001) observed that number of spikes m^{-2} was significantly higher under hand weeding + hoeing followed by hand weeding at 20 DAS, hand weeding at 20 and 40 DAS and isoproturon @ 1.5 kg ha^{-1} treated plots over weedy check. Pandey and Verma (2002) observed that number of productive tiller m^{-1} row length was significantly higher under hand weeding followed by isoproturon @ 1.0 kg ai ha^{-1} over weedy check. Aggarwal *et al.* (2003) reported that number of spikes m^{-2} was significantly higher under isoproturon @ 0.94 kg ha^{-1} as compared to weedy check. Pandey and Prakash (2003) observed that number of spikes m^{-2} increased with increasing duration of weed free condition and decreased with increasing weedy condition.

2.3.2.2 Number of spikelets spike^{-1}

Singh and Saha (2001) noted that lowest number of unfertile spikelets under hand weeding at 20 and 40 DAS. But fertile spikelets were significantly more in hand weeding (20 and 40 DAS) than other weed control treatments. Singh (2001) observed that different weed control methods did not differ significantly over weedy for fertile, sterile and total spikelets.

2.3.2.3 Number of grains spike^{-1}

Saini and Singh (2001) concluded that number of grains spike^{-1} was significantly higher under isoproturon @ 1.5 kg ha^{-1} as well as hand weeding, 40 and 70 DAS as compared to unweeded control. Pandey and Verma (2002) reported that grains ear^{-1} were significantly higher under hand weeding followed by isoproturon @ 1.0 kg ai ha^{-1}. The lowest number of grains was noted under weedy check. Maximum grains spike^{-1} were recorded in weed free while it was minimum under weedy check as well as isoproturon @ 1.0 kg ai ha^{-1} (Punia *et al.*, 2003). Pandey and Prakash (2003) observed that grain number spike^{-1} increased with increase in duration of weed-free condition and decreased with increased weedy condition.

2.3.2.4 1000-grain weight

Saini and Saha (2001) observed that 1000-grain weight was significantly higher under isoproturon @ 1.5 kg ha^{-1} and hand weeding, 40 and 70 DAS as compared to unweeded check. Pandey and Verma (2002) noted that 1000-grain weight was significantly higher under hand weeding followed by isoproturon @ 1.0 kg ai ha^{-1} as compared to weedy check. Pal (2002) reported that significantly higher 1000-grain weight under weed-free condition followed by isoproturon @ 1.0 kg ai ha^{-1} over weedy check. Punia *et al.* (2003) reported that weed control treatments did not affect 1000-grain weight significantly. Pandey and Prakash (2003) reported that weedy condition upto 40 DAS had no adverse-effect on 1000-grain weight. However, weedy condition beyond this stage resulted significant reduction when compared with full season weed-free condition.

2.3.2.5 Grain yield

Brar *et al.* (1995) observed that use of isoproturon gave significantly higher yield than unweeded control. Panwar *et al.* (1995) noted that isoproturon at 0.75 kg ai ha^{-1} applied 20 DAS gave a 52 per cent higher average grain yield over weedy check. Azad *et al.* (1997) noted the grain yield, on average was higher in isoproturon @ 0.75 kg ai·ha^{-1} over hand weeding and weedy check. Azad and Singh (1997) reported that pre and post emergence application of isoproturon @ 0.75 kg ai ha^{-1} gave higher grain yield than two hoeings and the weedy check. Post-emergence application of isoproturon was more effective than its pre-emergence application. Jain *et al.* (1998) noted highest grain yield with higher dose of isoproturon (1.875 kg ha^{-1}) followed by lower dose of isoproturon (1.25 kg ha^{-1}) and it was lowest in untreated control. Maximum seed yield was recorded in weed-free treatment followed by isoproturon at 0.75 kg ai ha^{-1} and @ 0.50 kg ai ha^{-1} (Chopra *et al.*, 2001).

Singh and Saha (2001) found that two hand weedings was better option to obtain maximum yield than other weed control methods. Singh (2001) reported significant increase in grain yield under different herbicidal treatments over weedy check. Pal (2002) reported significantly more grain yield under weed-free treatment followed by isoproturon than that of weedy check. Pandey and Verma (2002) reported that all the weed control treatments brought about significant increase in grain yield over the weedy check. Hand weeding resulted maximum increase and proved significantly superior to isoproturon @ 1.0 kg ai ha^{-1}. Similar findings were also put forth by Punia *et al.* (2003). Das and Verma (2003) observed significantly higher grain yield with isoproturon (1.0 kg ha^{-1} at 30 DAS) as compared to weedy check. Pandey and Prakash (2003) observed that grain yield increased with the increase in duration of weed free condition and decreased with increased weedy condition. Uncontrolled weeds resulted more than 69 per cent reduction in grain yield when compared with isoproturon at 1.0 kg ha^{-1}. Singh *et al.* (2003) reported that isoproturon at 1.0 kg ha^{-1} produced grain yield almost similar to that of weed-free.

2.3.2.6 Straw yield

Pal (2002) observed that uncontrolled weed reduced straw yield by 38 per cent when compared with weed free condition. Significantly higher straw yield was observed under weed-free treatment, followed by isoproturon @ 1.0 kg ai ha^{-1} over weedy check. Das and Verma (2003) reported significantly higher straw yield under isoproturon at 1.0 kg ha^{-1} at 30 DAS as compared with unweeded control. While, Mahajan and Sardana (2003) noted that isoproturon @ 0.94 kg ha^{-1} gave significantly lower straw yield as compared to unweeded check.

2.3.3 Weeds

2.3.3.1 Dominent weed species

Pandey and Verma (2002) noted *Avena ludoviciana, P. minor, C. album* and *Melilotus indica* as predominent weed species under weedy plot. Punia *et al.* (2003) noted wild canary grass and wild oat among grassy weeds and common lambsquarters, yellow sweet clover. (Rumex retroflexus L.) and swine grass, broad leaved as predominent weeds. While Aggarwal *et al.* (2003) observed *P. minor, C. album, M. denticulata* and *Rumex dentatus* major weed species. While Jat *et al.* (2003) reported *C. album, Chenopodium murale* L., *A. arvensis, Convolvulus arvensis* L. *Coronopus didymus* L., *Melilotus indica* L. and *P. minor* Retz. dominating weeds. Pandey and Prakash (2003) noted *Polygonum plebejub, A. arvensis* and *Stellaria media* as dominant weeds. Singh *et al.* (2003) reported *P. minor, C. album,* and others like *Rumex acetosella, A. arvensis, Fumeria parviflora, Melilotus* spp. and *Circium arvense as major weeds.* Whereas Singh *et al.* (2003) observed that the major weeds in weedy check at 60 DAS were : *Rumex spinosus* L., *C. album* L., *Syndrella noduflora* L., *Melilotus* sp., *A. arvensis* L. and *Vicia hirsuta* L. among broad-leaved weeds, and *P. minor* (Retz.), *Cynodon dactylon* (L.) Pers and *Cyperus rotundus* L. among narrow-leaved weeds.

2.3.3.2 Weed density

According to Hassan *et al.* (1994) post emergence application of isoproturon made at the 3-4 leaf stage of wheat reduced weed population to a minimum with all herbicide treatments. Isoproturon applied at 2.0 kg ha^{-1} had completely eradicated the weeds. Dixit *et al.* (1998) noticed that isoproturon just before irrigation provided better weed control as compared to its application at 30 DAS. Jain *et al.* (1998) noticed that the weed population was reduced significantly with isoproturon at 1.25 kg ha^{-1} as compared with the untreated control. Chauhan *et al.* (1998) revealed that grassy weed including *P. minor* may be managed by isoproturon application.

Singh *et al.* (2000) concluded that the lowest weed intensity was recorded under hand weeding at 30 DAS followed by isoproturon at 1.0 kg ai ha^{-1} (post-emergence application). But *Cyperus rotundus* and *Cynodon* were not controlled by isoproturon. Similar results were also recorded by Saini and Singh (2001). Chopra *et al.* (2001) noted that total weed population reduced significantly by isoproturon over weedy check. Higher dose of isoproturon (0.75 kg ha^{-1}) controlled the weed density more efficiently than lower dose. Weed control treatments significantly decreased weed population and in hand weeding, weed population was significantly lower than isoproturon @ 1.0 kg ai ha^{-1} and weedy check (Pandey and Verma, 2002). Significant decrease in total weed population was recorded under isoproturon @ 1.0 kg ha^{-1}, 30 DAS as compared to unweeded control. Application of isoproturon controlled the monocots particularly *P. minor* after wards (Das and Verma, 2003). Similar findings were also observed by Kim *et al.* (1998) and Kundra *et al.* (1999). Density of weeds decreased significantly due to different weed control treatments compared with untreated control at 60 DAS. Application of isoproturon at 1.0 kg ha^{-1} applied 35 DAS gave 62.5% control of grassy weeds (Punia *et al.*, 2003). Reduction in weed population due to isoproturon @ 1.0 kg ha^{-1} was 90, 90, 80, 30, 10 and 70 per cent in *P. minor, C. album, M. alba, M. indica, M. denticulata* and other weeds, respectively (Singh *et al.*, 2003).

2.3.3.3 Weed dry weight

Dhawan (1995) observed that the effect of 1.0 kg ha^{-1} isoproturon at 2 leaf stage of wheat, decreased dry matter accumulation per plant by 60 per cent in *Phalaris minor* and 69 per cent in *Avena ludoviciana.* Azad *et al.* (1997) reported that isoproturon at 0.50 and 0.75 kg ha^{-1} significantly reduced the dry weight of weeds as compared to hand weeding and the control. Gaffer *et al.* (1997) found that dry weight of weeds at harvest decreased due to different weeding treatments and critical period of weed competition ranged from 20 to 40 DAS.

Singh *et al.* (2000) concluded that the lowest dry biomass was recorded under hand weeding at 30 DAS followed by isoproturon at 1.0 kg ai ha^{-1} (post-emergence application). Similar results were also observed by Saini and Singh (2001). Chopra *et al.* (2001) noted that total weed dry weight reduced significantly by isoproturon over weedy check. Higher dose of isoproturon (0.75 kg) controlled the weed dry weight more efficiently than lower dose. Weed control treatments significantly decreased weed dry weight. In hand weeding, dry weight of weeds was significantly lower than isoproturon @ 1.0 kg ai ha^{-1} and weedy check (Pandey and Verma, 2002). Significant decrease in total weed dry weight was observed under isoproturon @ 1.0 kg ha^{-1}, 30 DAS as compared to unweeded control (Das and Verma, 2003). Similar findings were also observed by Kim *et al.* (1998) and Kundra *et al.* (1999). Singh *et al.* (2003) reported that species wise total dry weight was lowest under isoproturon at 1.0 kg ha^{-1} than other weed control treatments and the weedy.

2.3.3.4 Weed-control efficiency

Chopra *et al.* (2001) observed that weed control efficiency under isoproturon @ 0.75 kg ai ha^{-1} was higher than isoproturon @ 0.5 kg ai ha^{-1}. Whereas, Singh and Saha (2001) revealed that among different weed control measures, higher weed control efficiency was noted under two hand weeding followed by isoproturon and single hand weeding. Pal (2002) concluded that, significantly higher weed control efficiency under isoproturon than other weed control treatments. Singh *et al.* (2003) also reported that weed control efficiency under hand weeding (30 and 45 DAS) was higher (92.91%) as compared to weedy check (9.35%).

2.3.3.5 Crop weed competition index

Chopra *et al.* (2001) observed that crop weed index was lower under higher dose of isoproturon @ 0.75 kg ai ha^{-1} than lower dose of isoproturon @ 0.5 kg ai ha^{-1}. Singh and Saha (2001) revealed that among different weed control measures, lowest weed index was noted under two hand weeding followed by isoproturon and single hand weeding. Pal (2002) concluded that significantly lower weed index was under isoproturon than other weed control treatments. Pandey and Prakash (2003) reported that weed control index decreased with increase in duration of weed free condition and increase with increase in weedy condition.

2.3.4 Nutrient uptake

2.3.4.1 Nutrient uptake by crops

Wheat plant had lower content of nitrogen, phosphorus and potassium as compared to weeds associated with it (Pandey and Rao, 1965 and Nanda and Patro, 1996).

Kumar *et al.* (1997) reported that in weedy plots, crop removed 29.5 kg N, 19.2 kg P and 22.1 kg K ha^{-1} at 90 days stage of crop growth. Kumar *et al.* (1998) observed that under isoproturon (G) at 0.75 kg ai ha^{-1} applied before or after first irrigation caused a significantly higher uptake of nutrients than the weedy check. Walia *et al.* (2000) reported that uptake of N by unweeded crop was significantly lower than that of isoproturon treatments. Post-emergence application of isoproturon at 0.94 and 1.41 kg ha^{-1} increased wheat N-uptake by 38.0 and 47.3% over the control, respectively.

Singh and Saha (2001) observed that nutrient uptake (N, P and K) by crop was found significantly higher under hand weeding at 20 and 40 DAS (73.0, 26.7 and 82.3 kg ha^{-1}) followed by hand weeding, 20 DAS (65.7, 24.5 and 74.9 kg ha^{-1}) and isoproturon @ 1.5 kg ha^{-1} (55.5, 18.3 and 72.8 kg ha^{-1}) over weedy check treatment (24.5, 12.7 and 68.8 kg ha^{-1}).

2.3.4.2 Nutrient removal by weeds

Bainade and Patel (1991) reported that unweeded plots removed 13 kg N, 3.2 kg P and 12.3 kg K ha^{-1} by weeds. Johri *et al.* (1992) reported that uncontrolled weeds over a period of 90 days depleted on average 69, 15 and 52 kg ha^{-1} N, P and K. Removal of N P K was greatest in grassy, least in sedges, and moderate in broad leaved weeds. Application of 1.0 kg ai ha^{-1} of isoproturon was superior to 0.5 kg ai in reducing NPK removal by weeds.

Kumar *et al.* (1997) reported that in weedy plots on an average, weeds removed 78.2 kg N, 19.4 kg P and 85.6 kg K ha^{-1} at 90 days stage of crop growth. Kumar *et al.* (1998) observed that weeds removed 57, 13 and 28 kg N, P and K ha^{-1}, respectively.

Jaggi *et al.* (2000) observed in untreated control weeds used 26.84, 3.04 and 22.38 kg ha^{-1}, N, P and K, respectively compared to 7.07, 0.83 and 6.03 kg ha^{-1} for hand-hoed plots and 10.90, 1.23 and 8.80 kg ha^{-1} in plots treated with herbicides. Singh and Saha (2001) observed that the nutrient removal (N P K) by weeds was significantly more under weedy check (16.2, 10.5 and 19.7 kg ha^{-1}) followed by isoproturon @ 1.5 kg ha^{-1} as post-emergence (6.1, 3.8 and 7.8 kg ha^{-1}) and hand weeding, 20 DAS (4.5, 2.6 and 7.1 kg ha^{-1}). Lowest removal of NPK dry weeds was noted under hand weeding at 20 and 40 DAS (2.5, 1.8 and 5.2 kg ha^{-1}). Pal (2002) reported that isoproturon @ 1.0 kg ai ha^{-1} significantly reduced the N, P and K removal by weeds as compared to weedy check. Mahajan and Sardana (2003) concluded that the uptake of N, P and K by *P. minor* was highest in weedy plots and was least in plots treated with isoproturon @ 0.94 kg ha^{-1}. Uncontrolled weeds at harvest stage depleted on an average 28.6, 4.2 and 44.4 kg N, P and K ha^{-1}, respectively. Application of isoproturon led to 14.8% and 6.2% less removal of N and K by *P. minor*, respectively.

2.3.5 Economics

Singh and Saha (2001) revealed that two hand weeding resulted maximum net returns followed by isoproturon @ 1.5 kg ha^{-1} and single hand weeding over weedy check. Isoproturon @ 1.0 kg ha^{-1}, 30 DAS was found most remunerative. Incomparison to control (weedy) chemical weed control methods gave higher grass return, net return and net return $rupee^{-1}$ invested (Das and Verma, 2003).

2.4 Interaction effect

2.4.1 Tillage and seed rate

Kaspar and Fischbeck (1988) observed that weed density in drilled direct or after ploughing at 300, 375 and 450 seeds m^{-2} was markedly higher upto start of stem elongation stage with direct drilling than with ploughing, but differed little at and after ear emergence stage. Weed biomass and ground cover was always highest with direct drilling and at later stages was related inversely to sowing rate.

Kaspera and Fischbeck (1988) studied that grain yield on ploughed plots increased in the range 4.3 to 5.2 t ha^{-1} as sowing rate increased. After direct drilling, yield was highest at 4.4 t ha^{-1} at the intermediate seed rate. Differences were ascribed in part to competition for light. Srivastava *et al.* (2002) found that conventional tillage operations were superior than zero-tillage at all seed rates as regards to effective tillers m^{-2}, spikelets $spike^{-1}$ and yield.

2.4.2 Seed rate and weed control methods

Andersson (1988) reported that weed weight in plots sown at recommended rate (600 seeds m^{-2}) and treated with a broad-spectrum herbicide, was 10-15 per cent lesser of the weed dry weight in the corresponding unsprayed plots.

Andersson (1988) studied that higher grain yield was obtained at the higher seed rate in unsprayed plots, though at lower seed rates, sprayed plots generally out yielded than unsprayed plots. Gaffer *et al.* (1997) found that sowing at 125 kg ha^{-1} and weeding, 20 and 40 DAS were better for higher yield.

2.4.3 Tillage and weed control methods

Rorzak *et al.* (1991) observed that no-tillage led to considerable yield losses, especially in the absence of herbicides than conventional tillage. Application of pre-emergence herbicide use in no-tillage gave similar yield to that in conventional tillage (Keeling, 1995).

Clementus *et al.* (1995) reported that weed management represented 20-25 per cent of annual energy cost and eliminating tillage was more energy efficient than eliminating herbicide use which resulted into the lowest energy budget for weed control. It was concluded that reduced herbicide and reduced tillage were more energy efficient than conventional weed control practices.

Conventional tillage along with isoproturon @ 1.0 kg ha^{-1} proved effective for reducing the weed biomass and obtained highest grain yield of wheat than minimum and no-tillage practices (Dixit and Bhan, 1996-97).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Details of experimental materials used, procedures followed and techniques adopted during the course of investigation are described here:

3.1 Experimental site

Field experiment was carried out during *Rabi* 2002-03 and 2003-04 in C_2 block at Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (29°N latitude, 79°29'E longitude and 243.8 m altitude), U.S. Nagar (U.A.). The Crop Research Centre is situated in *Tarai* belt south of the foothills of Shivalik range of Himalayas.

3.2 Climate and weather

Pantnagar enjoys sub-humid, subtropical climate with hot dry summer and cool winters. Generally, monsoon starts in the last week of June and out 1364 mm mean annual rainfall at Pantnagar, 80-90 per cent is normally received from June to September. Very often few showers are expected during winters and occasionally during summer months. May-June months experience maximum temperature (41°C) while December-January are most often cool months (minimum temperature 1-2°C). Mean relative humidity (7.00 AM) remains almost 91 to 60 per cent from mid-November to end of April. Weekly average of meteorological data during the course of experimentation as recorded at Meteorological Observatory, Crop Research Centre, Pantnagar are presented in Appendix-Ia and Ib and depicted in Fig.1a and 1b.

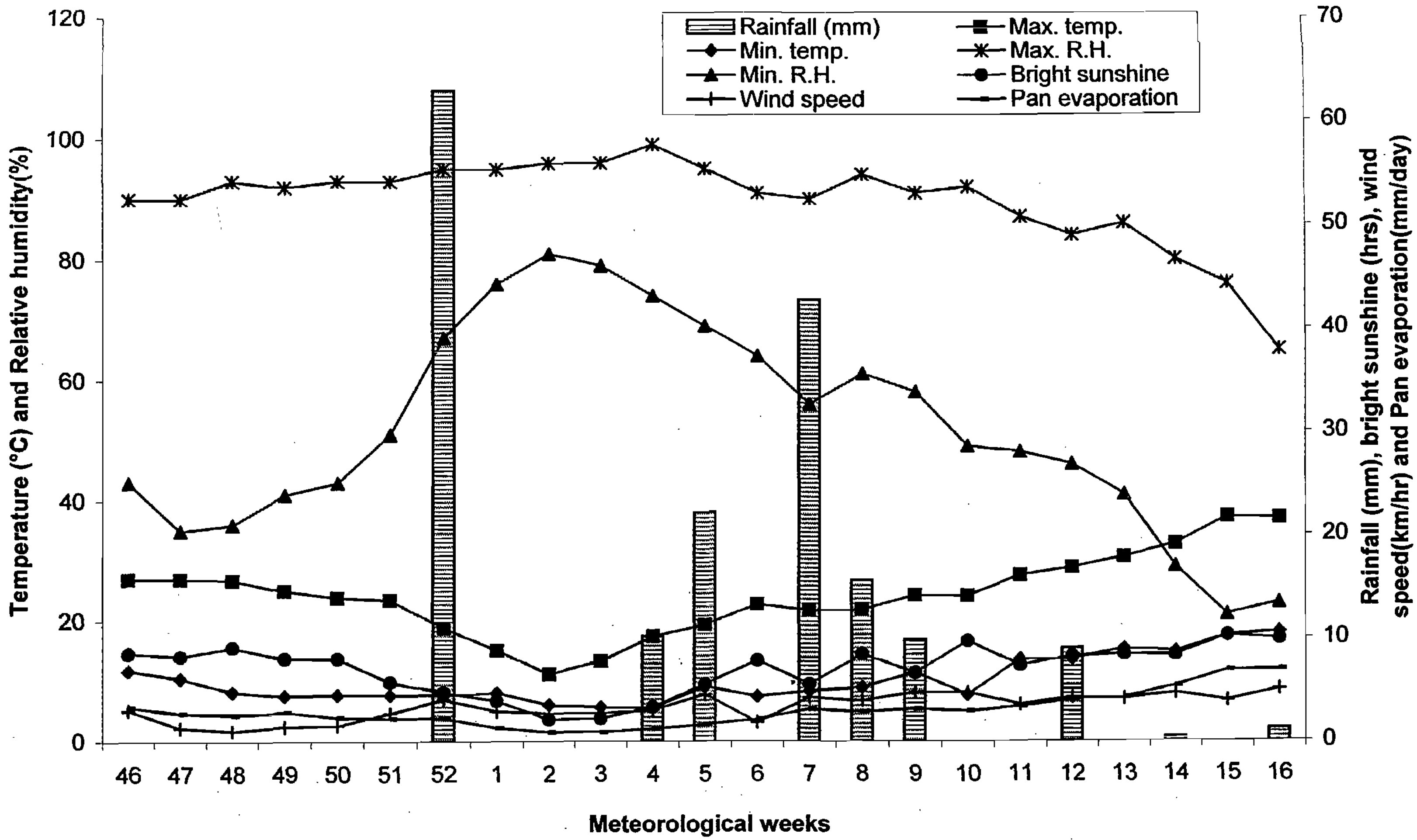


Fig.1a : Weekly weather conditions during crop season 2002-03

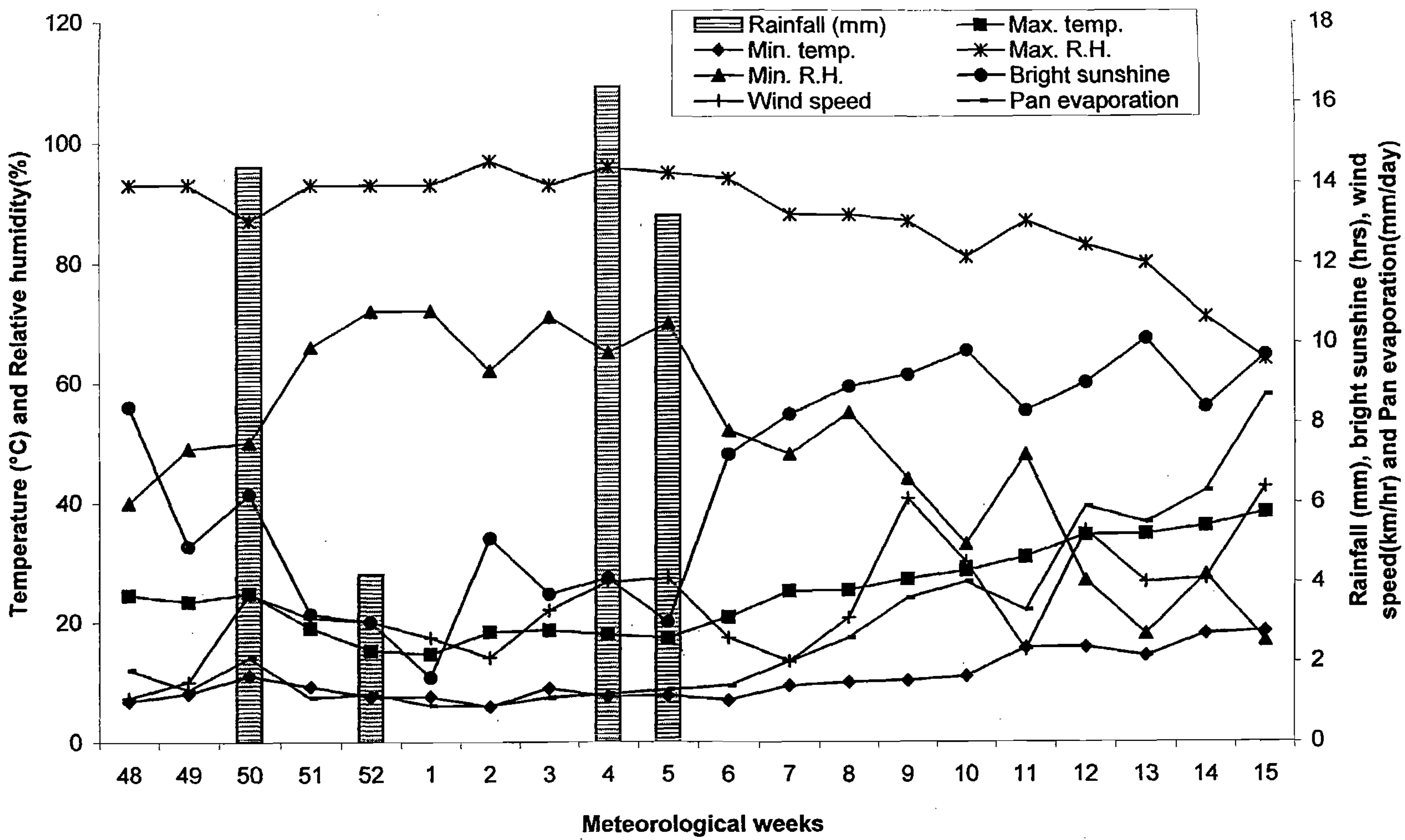


Fig.1b : Weekly weather conditions during crop season 2003-04

During the crop season mean maximum temperature ranged from 11.1°C to 37.2°C in 2002-03 and from 14.6°C to 38.4°C in 2003-04. While mean minimum temperature ranged from 5.5°C to 18.1°C in 2002-03 and from 5.8°C to 18.5°C in 2003-04. Relative humidity at 7.00 AM ranged from 65 to 99 per cent during 2002-03 and 64 to 97 per cent during 2003-04. While relative humidity at 2.00 PM ranged from 21 to 81 per cent during 2002-03 and 17 to 72 per cent during 2003-04. Total rainfall received during crop period was 174.2 mm during 2002-03 and 48.2 mm during 2003-04. Daily pan evaporation ranged from 0.9 to 6.9 mm day^{-1} in 2002-03 and from 0.9 to 8.7 mm day^{-1} in 2003-04. Wind velocity ranged from 1.0 to 5.0 km hr^{-1} in 2002-03 and 1.5 to 6.4 km hr^{-1} in 2003-04. Bright sunshine hours ranged from 2.1 to 10.2 hrs in 2002-03 and 1.6 to 10.1 hrs in 2003-04.

3.3 Soil characteristics

Composite soil sample from experimental area collected at 0-15 cm depth was analyzed for different constituents. Soil of the experimental area was clay loam in texture, high in organic carbon, medium in available phosphorus and rich in available potassium with neutral pH (Table 1).

3.4 Cropping history

Maize-wheat sequence was followed for last three years in the experimental area.

Table 1: Physico-chemical properties of soil (0-15 cm depth)

S. No.	Properties	Value		Method used
		2001	2002	
1.	Particle size			
	Sand (%)	26.20	26.12	International pipette method (Page *et al.*, 1982)
	Silt (%)	28.09	28.03	
	Clay (%)	45.71	45.85	
2.	Total nitrogen (%)	0.078	0.094	Macro Kjeldahl method (Jackson, 1973)
3.	Available nitrogen (kg N ha^{-1})	240	236	Alkaline $KMnO_4$ method (Nelson and Sommers, 1982)
4.	Available phosphorus (kg P ha^{-1})	19.10	19.44	Olsen's method (Olsen *et al.*, 1954)
5.	Available potassium (kg K ha^{-1})	246.8	243.5	Neutral Normal ammonium acetate method (Page *et al.*, 1982)
6.	Organic carbon (%)	0.91	1.08	Modified Walkley and Black method (Jackson, 1973)
7.	Soil pH (1:2.5, soil : water)	7.4	7.3	Beckman glass electrode pH meter (Jackson, 1973)

3.5 Experimental details :

Experiment was conducted in split-plot design keeping tillage x seed rate in main-plots and weed control method in sub-plots with three replications. Layout plan is depicted in Fig.2.

Treatments:

A. Main-plot

a. Tillage

i. Till

ii. No-till

b. Seed rate (kg ha^{-1})

i. 100

ii. 150

iii. 200

B. Sub-plot

Weed control method:

i. Hand weeding at 30 days after sowing (DAS)

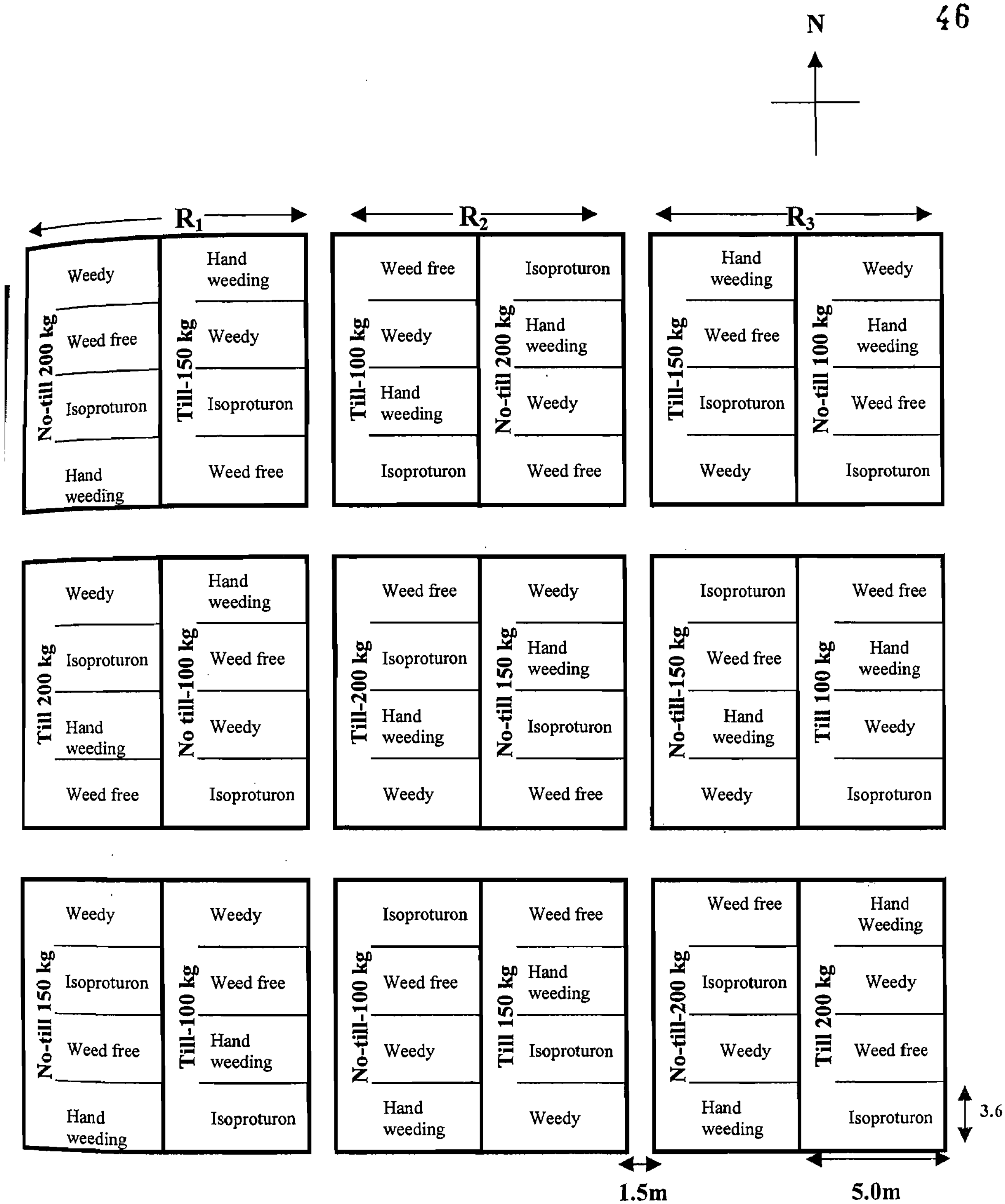
ii. Isoproturon @ 1.0 kg ai ha^{-1} at 35 days after sowing (DAS)

iii. Weed free

iv. Weedy check

3.6 Crop culture

Schedule of different cultural operations is given in Table 2. For till treatment field was prepared with tractor drawn implements. It was ploughed once by disc plough followed by cross disc harrowing and levelling. After pre-



Experimental details

Design : Split plot design

Replication : 3

Gross plot size : 3.6 m x 5 m = 18 m^2

Net plot size : 2.25 m x 4 m = 9 m^2

Fig. 2 : Layout plan of the experiment

Table 2 : Schedule of cultural operations

S. No.	Operations	Year		Method/ Implements used
		2002-03	2003-04	
1.	Ploughing and rolling (till)	29.10.02	12.11.03	Tractor drawn disc plough and roller
2.	Harrowing, chrurning and planking (till)	13.11.02	28.11.03	Tractor drawn disc harrow, rotavator and planker
3.	Paraquat spray (no- till)	7.11.02	23.11.03	Manual, Maruti Foot Sprayer
4.	Layout	14.11.02	30.11.03	Manual
5.	Fertilizers application			
	(i) Basal	14.11.02	30.11.03	Manual broadcasting
	(ii) Top dressing	8.12.02	16.01.04	Manual broadcasting
6.	Sowing	15.11.02	1.12.03	Manual, Tractor drawn Furrow opener
7.	Bunding	22.11.02	8.12.03	Manual, Tractor drawn bund maker
8.	Irrigation			
	I pre-sowing	30.10.02	16.11.03	Manual
	II post-sowing	5.12.02	-	
	III post-sowing	-	12.01.04	
	IV post-sowing	29.03.03	11.03.04	
9.	Hand weeding	15.12.02	02.01.04	Manual, khurpi
10.	Isoproturon spray	20.12.02	6.01.04	Manual, Maruti Foot sprayer
11.	Harvesting	21.04.03	6.04.04	Manual, sickle
12.	Weighing	24.04.03	11.04.04	Manual, spring balance
13.	Threshing	25.04.03	12.04.04	Pullman thresher

sowing irrigation, field was prepared giving two harrowing, one rotavator operation and levelling during both the years.

For no-till plots to kill vegetation, paraquat @ 0.5 kg ai ha^{-1} was sprayed one week before sowing with the help of Maruti Foot Sprayer for pre-plant dessication during both the years.

All the plots were fertilized uniformly using 120 kg nitrogen, 60 kg phosphorus and 40 kg potassium per hectare through urea, single super phosphate and murate of potash, respectively. Half dose of nitrogen, full dose of phosphorus and potassium were applied and mixed thoroughly in soil just before sowing. Remaining quantity of nitrogen was top-dressed three days after first irrigation.

Seeds of wheat cv. 'UP-2382' on November 15, 2002 and cv. 'UP-2425' on December 1, 2003 was drilled as per seed rate treatment. Furrows were opened 22.5 cm apart with the help of tractor drawn furrow opener.

Crop was irrigated as per the need after crop, two and three irrigations were required during 2002-03 and 2003-04, respectively.

Isoproturon was sprayed in aqueous medium at the rate of 500 litre water per hectare with the help of Maruti Foot Sprayer fitted with flat-fan nozzle. Application of isoproturon was made at 35 DAS. Details of isoproturon used in the experiment are given in Appendix-II.

Harvesting was done on April 21 and April 6, during 2003 and 2004, respectively. Before harvesting of the net plot area the border was marked all around and harvested. Net plot area was harvested, bundled, and threshed plot wise individually with the help of a Pullman thresher.

3.7 Studies and observations

On north side of each plot, two metre row length of crop was marked in the third row for recording observations i.e. plant height, shoot number and post harvest studies while on opposite side of the plots, after leaving two border rows, the area of third and fourth row was used for observations on weeds, leaf area and plant dry matter. Half metre area from remaining after two sides (from length) of the plot was kept as border.

3.7.1 Crop studies

3.7.1.1 Growth and development

3.7.1.1.1 Plant stand

Plant stand (m^{-2}) count was made at 20 DAS when the total number of plants in the marked area imerged completely.

3.7.1.1.2 Number of shoots

Shoot number was recorded at 30, 60, 90 and 120 DAS by counting number of shoots from two metre row length of the crop in the marked third row in each plot for observations and finally expressed as a number of shoots m^{-2}.

3.7.1.1.3 Plant height

Plant height (cm) of the crop was recorded from the earmarked two metre row length area. Plant height of 10 shoots was measured at 30, 60, 90 and 120 DAS with the help of a metre scale from the base of the plant to the tip of the tallest leaf before emergence of spike and upto the tip of spike after emergence of spike. It was averaged and reported as plant height.

3.7.1.1.4 Leaf area index

Ten shoots were taken randomly and all the functional leaves were separated from the culms. Leaf area of all the leaves was measured with the help of automatic leaf area meter at 30 and 120 DAS. But on 60 and 90 DAS, half the representative leaves were taken and leaf areas was calculated. Leaf area was reported as cm^{-2} $plant^{-1}$ and finally leaf area was converted to $cm^{-2}m^{-2}$ by multiplying with the plant population m^{-2}. Leaf area index was calculated for each plot as per given formula:

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.7.1.1.5 Plant dry weight

Dry matter of shootswas determined at 30, 60, 90 and 120 DAS of crop. Shoots from 0.25 m row length were cut close to the ground surface from each plot. After air drying the samples, a constant weight in a hot air oven maintained at a temperature of 65°C±5°C for 48 hours, data was reported as g m^{-2}.

3.7.1.1.6 Mean crop growth rate ($\overline{CGR}$)

Data recorded for plant dry weight studies was used for computation of $\overline{CGR}$ and $\overline{RGR}$ (Redford, 1967). Mean crop growth rate ($\overline{CGR}$) was computed by using the following formula:

$$\overline{CGR} = \frac{w_2 - w_1}{t_2 - t_1} \text{ g day}^{-1} \text{ m}^{-2}$$

where, w_1 and w_2 are total plant dry weight at time t_1 and t_2, respectively. It was calculated for the intervals 30-60, 60-90 and 90-120 DAS and expressed as g day^{--1} m^{-2}.

3.7.1.1.7 Mean relative growth rate ($\overline{RGR}$)

Mean relative growth rate was calculated as follows :

$$\overline{RGR} = \frac{l_n w_2 - l_n w_1}{t_2 - t_1} \text{ g g}^{-1} \text{ day}^{-1} \text{ m}^{-2}$$

where, $w_1$and w_2 are total plant dry weight at time t_1 and t_2, respectively. It was calculated for the intervals 30-60, 60-90 and 90-120 DAS and expressed as g g^{-1}day^{-1} of dry weight m^{-2}.

3.7.1.1.8 Root growth

a. Sampling of the root

Root samples were taken with the help of core sampler by selecting a representative hill in the plot and it was cut from the base. The core sampler was hammered into the soil to 100 mm depth and pulled out after twisting 2-3 times. Again core sampler was pushed to the next 100 mm depth increment, after removing the root sample into a bucket. Samples were taken until no root was visible in the sample.

b. Root washing

These samples were soaked in water and the roots were washed in a soil root wash basin consisting of a 0.40 x 0.25 x 0.30 m deep metal tank. Clean roots were collected in bottles containing 5 per cent formalin solution.

Root growth and distribution were studied having observations on root length density and dry weight.

c. Root length density

Wet roots were placed in a flat glass tray containing small amount of water. Graph paper, ruled in millimeters was placed under the tray. The roots were straightened with forceps so that they did not over lap and were held in position by a glass plate. Length of roots or root segments was counted by eye inspection. A magnified glass was used for fine roots, as described by Newman (1966) which was further modified by Tennant (1975) using 10 x 10 mm size grid. Later root length was calculated as below:

Root length (mm) = 0.786 x number of intersections x grid unit

Root length density was calculated from the total root length and sample volume. Sample volume referred to the volume of the core removed for root study and expressed:

$$V = \pi r^2 h$$

where,

v	=	Volume of the sample (cm^3)
r	=	radius of the core sampler (cm)
h	=	depth of sample (cm)

Finally root length density was calculated using the following formula:

$$\text{Root length density (cm cm}^{-3}\text{)} = \frac{\text{Total root length (cm)}}{\text{Volume of core (cm}^3\text{)}}$$

d. Root dry weight

Preserved roots were dried in an oven at 65 ± 5°C for about 12 hours and root dry weight(mg) was determined.

3.7.1.1.9 Days taken to heading

Date by which 50 per cent ears completely emerged out of flag leaf sheath it was noted as the date of 50 per cent heading. Days from sowing to this date were computed and reported as days taken to heading.

3.7.1.1.10 Days taken to maturity

The date on which about 75 per cent shoots turned yellow was noted visually and a regular monitoring was done for ascertaining the days taken to maturity. The number of days from sowing to this date was calculated and reported as days taken to maturity.

3.7.1.1.11 Reproductive period

Days from heading to maturity were calculated by substracting the days taken to heading from the days taken maturity and it was expressed as reproductive period.

3.7.1.2 Yield and yield attributes

3.7.1.2.1 Number of spikes

Number of spikes were recorded from two metre row length, marked for observations and expressed as number of spikes $metre^{-2}$. Ten spikes were sampled in each plot from the same area to record the following observations.

3.7.1.2.2 Spike length

Length of ten spikes sampled was measured and its average was reported as spike length (cm).

3.7.1.2.3 Number of fertile spikelets

Number of fertile spikelets $spike^{-1}$ was counted from ten spikes and average number was expressed as number of fertile spikelets $spike^{-1}$.

3.7.1.2.4 Number of sterile spikelets

All the spikelets $spike^{-1}$, which did not bear grain, were counted from the ten spikes and averaged to give the number of sterile spikelets $spike^{-1}$.

3.7.1.2.5 Number of grains

Number of grains $spike^{-1}$ from the sampled 10 spikes were counted after threshing and average number of grains was expressed as number of grains $spike^{-1}$.

3.7.1.2.6 Grain weight

Total grains obtained from the selected ten spikes were weighed, averaged and reported as grain weight $spike^{-1}$ (g).

3.7.1.2.7 1000-grain weight

Five hundred grains from net plot sample were counted, weighed and 1000-grain weight (g) was worked out by multiplying it with two.

3.7.1.2.8 Biological yield

Weight of total produce per net plot was weighed before threshing and recorded in kg plot^{-1}. Later, it was converted and expressed as kg ha^{-1}.

3.7.1.2.9 Grain yield

Weight of grains from the harvested and threshed net plot area was recorded in kg plot^{-1} after cleaning and it was expressed as kg ha^{-1} at 14 per cent moisture content.

3.7.1.2.10 Straw yield

Straw yield was computed by subtracting the grain yield from the biological yield of the net plot area and it was expressed in kg ha^{-1}.

3.7.1.2.11 Grain: Straw ratio

It was estimated by dividing the grain yield by the straw yield of the net plot.

3.7.2 Weed studies

3.7.2.1 Dominant weeds

At different stages visual rating was done for dominant weed species from each plot and it was reported as dominant weeds.

3.7.2.2 Weed density

Random sampling of weeds at 30, 60, 90 and 120 DAS from each plot was done, using a quadrate of 50 cm x 50 cm (0.25 m^2) from the area marked for weed studies these were cut close to the ground surface, categorised and counts were made. Later these were converted and reported as number of weeds metre^{-2}.

3.7.2.3 Weed dry weight

All the counted weeds were collected in paper bags at 30, 60, 90 and 120 DAS and dried in drier at 65 ± 5°C till constant dry weight. After recorded dry weight it was multiplied by four and reported as g m^{-2}.

3.7.2.4 Weed control efficiency (WCE)

It was worked out as per formula given by Kondop and Upadhyay (1985).

$$\text{Weed control efficiency (WCE \%)} = \frac{x - y}{x} \times 100$$

where,

x	=	weed dry weight in weedy plot
y	=	weed dry weight in treated plot

3.7.2.5 Crop-weed competition index

It was calculated using the following formula and expressed in percentage:

$$\text{Crop-weed competition index} = \frac{a - b}{a} \times 100$$

where,

a	=	Grain yield in weed free plot
b	=	Grain yield in treated plot

3.7.3 Chemical studies

Representative samples of grain and straw of wheat and weeds were collected from each plot at the time of harvesting in wheat and 60 DAS in weeds. These samples were dried at 65 ± 5°C temperature till the constant dry weight. Dried samples were grind and used for chemical analysis.

3.7.3.1 Nitrogen content and uptake

Nitrogen content (%) in grain, straw and weeds separately was determined as per modified Micro kjeldahl method (Jackson, 1973). Nitrogen uptake (grain and straw) and removal (weeds) for each treatment was calculated as below:

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content (\%) x Dry matter (kg ha}^{-1}\text{)*}}{100}$$

*Oven dried weight of grain, straw and weeds

3.7.3.2 Phosphorus content and uptake

Phosphorus content (%) in grain, straw and weeds separately was determined by adopting molybdo-vanadophosphoric yellow colour method using blue filter (Jackson, 1973). Phosphorus uptake by grain, straw and weeds for each treatment was calculated as below:

$$\text{Phosphorus uptake (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus content (\%) x Dry matter (kg ha}^{-1}\text{)*}}{100}$$

* Oven dried weight (kg ha^{-1}) of grain, straw and weeds

3.7.3.3 Potassium content and uptake

Potassium content (%) in grain, straw and weeds separately was determined by using flame photometry (Jackson, 1973). Potassium uptake (grain and straw) and removal (weeds) for each treatment was calculated as below:

$$\text{Potassium uptake (kg ha}^{-1}) = \frac{\text{Potassium content (\%) x Dry matter (kg ha}^{-1})^{*}}{100}$$

* Oven dried weight (kg ha^{-1}) of grain, straw and weeds

3.7.4 Economic studies

3.7.4.1 Cost of cultivation

Cost of cultivation (Rs. ha^{-1}) of individual treatments was worked out on the basis of prevailing local market prices for different inputs i.e. labour, implements, seeds, fertilizer and other chemicals.

3.7.4.2 Gross return

Economic yield (grain and straw) of wheat was converted into gross return in rupee based on the local market price of different commodities.

3.7.4.3 Net return

Net return (Rs.ha^{-1}) of each treatment was calculated by deducting the cost of cultivation of individual treatment from the gross return of individual treatment.

3.7.4.4 Net return per rupee invested

Net return per rupee invested (Rs.) was calculated as follows:

$$\text{Net return per rupee invested} = \frac{\text{Net return (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

3.7.5 Statistical analysis

Allocation of treatments to the plots was made by using random numbers. Data on different characters were analysed by using the analysis of variance (ANOVA) technique for split-plot design as suggested by Chochran and Cox (1959). The data on weed population and weed dry matter were analysed after applying log (x+1) transformation. Test of significance of the treatment differences was done on the basis of 'F' test. Comparison of treatment means was done using C.D. at 5% level of significance.

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

Significant results obtained during the course of experimentation are presented here with the help of suitable tables and diagrams.

4.1 Growth and development studies

4.1.1 Plant stand

Plant stand (m^{-2}) at 20 DAS was higher during 2002-03 than 2003-04 and differed significantly due to different tillage practices and seed rate. But weed control method did not cause significant variation in plant stand (Table 3 and Appendix-III).

During both the years significantly higher plant stand was recorded under tillage as compared to no-till treatment.

Plant stand increased significantly with increase in seed rate during both the years. Maximum plant stand noted under 200 kg seed rate was significantly superior over 100 and 150 kg seed rate during both the years. Plant stand was also significantly more with 150 kg than 100 kg seed rate.

4.1.2 Number of shoots

Shoot number (m^{-2}) was higher during 2002-03 than 2003-04 at all the growth stages. Number of shoots increased upto 60 DAS and 90 DAS during 2002-03 and 2003-04, respectively and later decreased. Number of shoot

Table 3: **Plant stand (no. m^{-2}) at 20 DAS as influenced by tillage, seed rate and weed control method**

Treatments	Plant stand 20 DAS	
	2002-03	**2003-04**
Tillage		
Till	195	175
No-till	164	150
S.Em.±	4	4
C.D. (P=0.05)	12	12
Seed rate (kg ha^{-1})		
100	139	121
150	182	167
200	218	201
S.Em.±	5	5
CD (P=0.05)	15	15
Weed control method		
Hand weeding at 30 DAS	173	162
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	179	158
Weed-free	191	171
Weedy check	176	160
S.Em.±	6	5
CD (P=0.05)	NS	NS

Table 4: Number of shoot (m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages

Treatments	Number of shoot (m^{-2})							
	Days after sowing (DAS)							
	2002-03				2003-04			
	30	60	90	120	30	60	90	120
Tillage								
Till	422	591	524	488	299	420	473	433
No-till	332	515	472	437	269	388	427	393
S.Em.±	13	12	10	8	8	9	11	10
C.D. (P=0.05)	40	38	33	26	25	30	36	30
Seed rate (kg ha^{-1})								
100	280	457	431	404	216	353	400	372
150	397	581	530	488	288	403	453	416
200	454	621	534	495	348	455	498	452
S.Em.±	16	15	13	10	10	12	14	12
CD (P=0.05)	49	46	40	31	31	36	44	37
Weed control method								
Hand weeding at 30 DAS	366	563	510	473	283	410	462	417
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	377	555	506	468	277	405	459	415
Weed-free	393	578	522	486	296	427	470	443
Weedy check	372	515	455	423	280	373	410	378
S.Em.±	10	14	18	15	7	11	14	12
CD (P=0.05)	NS	40	50	44	NS	30	40	33

differed significantly due to tillage, seed rate and weed control method (Table 4 and Appendix-IV).

Significantly higher number of shoots was noted under till than no-till treatment at all the stages during both the years.

Maximum number of shoots was noted under 200 kg seed rate which was significantly superior over 100 kg seed rate at all the stages during both the years. While number of shoots with 200 kg seed rate was significantly more than 150 kg seed rate at 30 DAS during 2002-03 and 30, 60 and 90 DAS during 2003-04. Significantly more number of shoot was obtained with 150 kg than 100 kg seed rate at all the stages during both the years.

All the weed control treatments resulted significantly more number of shoots than the weedy check at 60, 90 and 120 DAS during both the years. Significantly more number of shoots was noted with weed free being at par with hand weeding and isoproturon treatment than weedy check during both the years.

4.1.3 Plant height

Plant height (cm) increased with advancement in crop age during both the years. Significant differences in plant height were noted due to tillage, seed rate and weed control method (Table 5 and Appendix-V).

Significantly more plant height was recorded under no-till as compared to till treatment at 30 and 120 DAS during 2003-04.

Table 5: **Plant height (cm) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Plant height (cm)							
	Days after sowing (DAS)							
	2002-03				2003-04			
	30	60	90	120	30	60	90	120
Tillage								
Till	31.0	55.7	84.6	87.1	21.0	53.7	84.3	86.7
No-till	29.4	53.7	85.7	88.6	22.5	55.2	85.2	88.8
S.Em.±	0.5	0.8	0.6	0.5	0.3	0.8	0.5	0.4
C.D. (P=0.05)	NS	NS	NS	NS	0.9	NS	NS	1.2
Seed rate (kg ha^{-1})								
100	29.3	54.0	85.1	87.5	21.1	53.7	83.8	88.5
150	30.0	54.5	84.5	87.6	21.8	54.2	84.5	87.9
200	31.3	55.6	85.8	88.4	22.2	55.4	85.9	86.8
S.Em.±	0.6	0.9	0.7	0.6	0.4	0.9	0.6	0.5
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.8	1.4
Weed control method								
Hand weeding at 30 DAS	29.8	53.9	84.3	88.3	21.8	53.9	84.2	88.1
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	30.4	55.2	85.6	87.5	21.7	54.6	85.3	87.6
Weed-free	30.4	55.1	85.9	88.7	21.4	54.3	85.7	89.1
Weedy check	30.2	54.6	84.8	86.8	21.9	55.0	83.8	86.2
S.Em.±	0.6	0.6	0.6	0.5	0.4	0.9	0.8	0.8
CD (P=0.05)	NS	NS	NS	1.5	NS	NS	NS	2.4

Significantly taller plants were obtained with 200 kg seed rate over 100 kg seed rate at 90 and 120 DAS during 2003-04 only.

Significantly taller plants were recorded under weed free plots than that of weedy check at 120 DAS during both the years. Hand weeding was significantly superior over weedy check at 120 DAS during 2002-03 only.

4.1.4 Leaf area index (LAI)

Leaf area index increased with advancement of crop age upto 90 DAS and thereafter it declined during both the years. Tillage, seed rate and weed control method affected leaf area index significantly (Table 6, Fig. 3a & 3b and Appendix-VI).

Leaf area index was significantly higher under till than no-till treatment at 30 and 60 DAS during 2002-03 only.

Significantly higher leaf area index was noted with 200 kg seed rate as compared to 100 and 150 kg seed rate at 30 DAS during 2002-03 and at 30, 60 and 90 DAS during 2003-04. Further 150 kg seed rate was significantly superior over 100 kg seed rate. During 2002-03 at 60 DAS, 150 and 200 kg seed rate being at par resulted significantly more leaf area index over 100 kg seed rate, whereas at 90 DAS 150 kg seed rate resulted significantly more leaf area index over 100 kg seed rate.

All the weed control treatments resulted significantly more LAI than weedy check at all the growth stages except at 30 DAS during both the years.

Table 6: **Leaf area index (LAI) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Leaf area index (LAI)							
	Days after sowing (DAS)							
	2002-03				2003-04			
	30	60	90	120	30	60	90	120
Tillage								
Till	1.33	4.86	6.28	1.90	0.85	5.46	6.07	-
No-till	1.00	3.79	5.84	1.81	0.85	5.45	5.86	-
S.Em.±	0.03	0.12	0.15	0.04	0.02	0.10	0.11	-
C.D. (P=0.05)	0.11	0.39	NS	NS	NS	NS	NS	-
Seed rate (kg ha^{-1})								
100	0.87	3.57	5.78	1.83	0.62	4.70	5.07	-
150	1.21	4.65	6.38	1.91	0.84	5.39	5.99	-
200	1.41	4.75	6.02	1.82	1.08	6.27	6.84	-
S.Em.±	0.04	0.15	0.19	0.04	0.03	0.12	0.13	-
CD (P=0.05)	0.13	0.48	0.59	NS	0.08	0.39	0.42	-
Weed control method								
Hand weeding at 30 DAS	1.14	4.49	6.27	1.95	0.86	5.69	6.25	-
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	1.17	4.40	6.18	1.80	0.84	5.48	5.94	-
Weed-free	1.16	4.73	6.93	2.13	0.85	5.77	6.82	-
Weedy check	1.19	3.68	4.86	1.55	0.83	4.87	4.84	-
S.Em.±	0.03	0.12	0.18	0.05	0.02	0.16	0.15	-
CD (P=0.05)	NS	0.35	0.51	0.15	NS	0.45	0.43	-

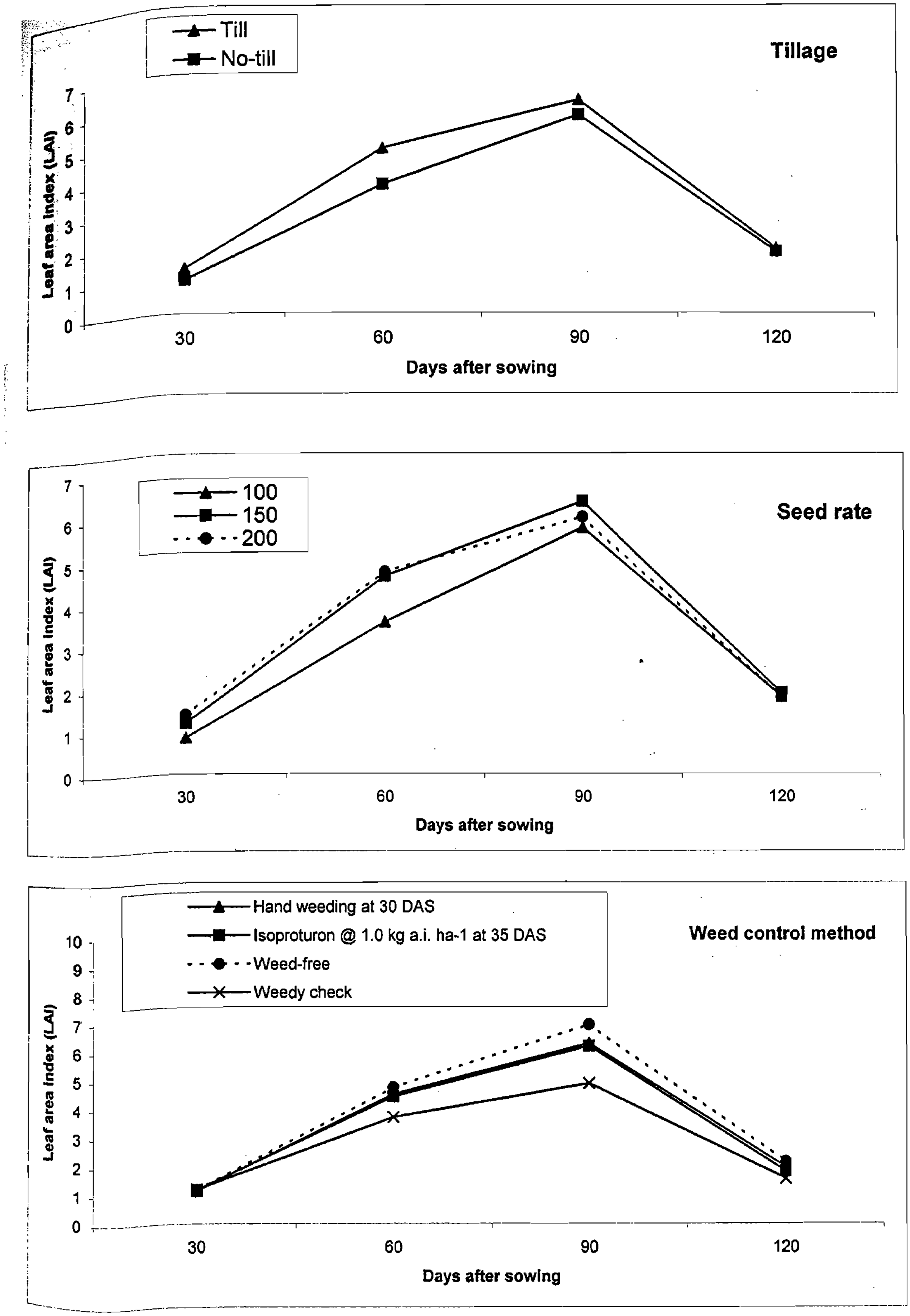


Fig. 3a: Leaf area index as influenced by tillage, seed rate and weed control method at different growth stages during 2002-03

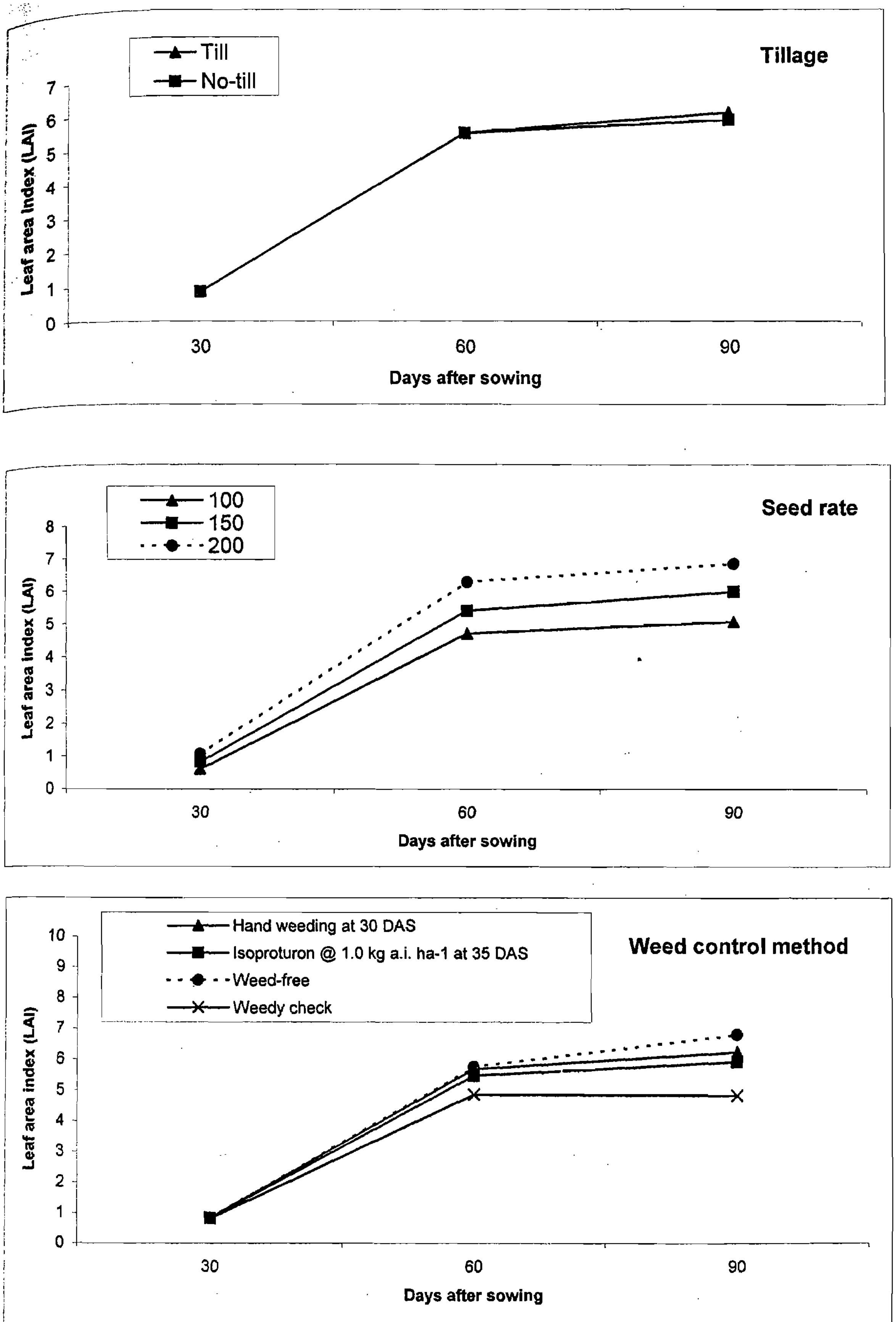


Fig. 3b: Leaf area index as influenced by tillage, seed rate and weed control method at different growth stages during 2003-04

Weed free treatment was significantly superior than weedy check at all the stages except at 30 DAS during both the years. At 60 DAS, weed free treatment which was at par with hand weeding and isoproturon treatments resulted significantly higher LAI than weedy check during both the years. At 90 DAS, hand weeding being at par with isoproturon was significantly superior than weedy check. During 2002-03 at 120 DAS, hand weeding caused significantly higher LAI than isoproturon and weedy check. Similarly, isoproturon resulted significantly more LAI than weedy check.

4.1.5 Plant dry weight

Plant dry weight (g m^{-2}) was higher during 2002-03 as compared to 2003-04 at all the stage of crop growth and it increased with advancement of crop age upto 120 DAS. Tillage, seed rate and weed control method resulted significant variation in plant dry weight (Table 7, Fig.4a & 4b and Appendix-VII).

Plant dry weight noted with tillage was significantly higher than that of no-till treatment at 30 DAS during both the years.

Significantly higher dry weight was noted due to 200 and 150 kg seed rate being at par than that of 100 kg seed rate at 30 and 60 DAS during 2002-03. Whereas during 2003-04 it was significantly higher at 30 DAS with 200 kg seed rate than that of 150 and 100 kg seed rate. Similarly dry weight with 150 kg seed rate was significantly higher than that of 100 seed rate. But dry weight

Table 7: **Plant dry weight (g m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Plant dry weight (g m^{-2})							
	Days after sowing (DAS)							
	2002-03				2003-04			
	30	60	90	120	30	60	90	120
Tillage								
Till	44.23	320	1029	1393	40.47	166	776	1146
No-till	38.39	303	944	1328	34.63	158	765	1143
S.Em.±	1.46	7	30	53	0.98	4	23	40
C.D. (P=0.05)	4.58	NS	NS	NS	3.10	NS	NS	NS
Seed rate (kg ha^{-1})								
100	34.57	275	946	1318	30.82	150	742	1118
150	42.19	327	1005	1418	38.45	165	782	1163
200	47.15	333	1007	1345	43.39	172	787	1152
S.Em.±	1.78	9	37	65	1.20	5	28	49
CD (P=0.05)	5.61	28	NS	NS	3.79	16	NS	NS
Weed control method								
Hand weeding at 30 DAS	40.31	332	1004	1415	37.79	162	779	1152
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	41.39	319	982	1368	36.74	160	751	1120
Weed-free	42.77	350	1132	1471	38.67	177	862	1234
Weedy check	40.75	245	826	1186	37.01	151	690	1072
S.Em.±	1.24	9	35	55	0.89	3	21	40
CD (P=0.05)	NS	25	99	158	NS	9	61	114

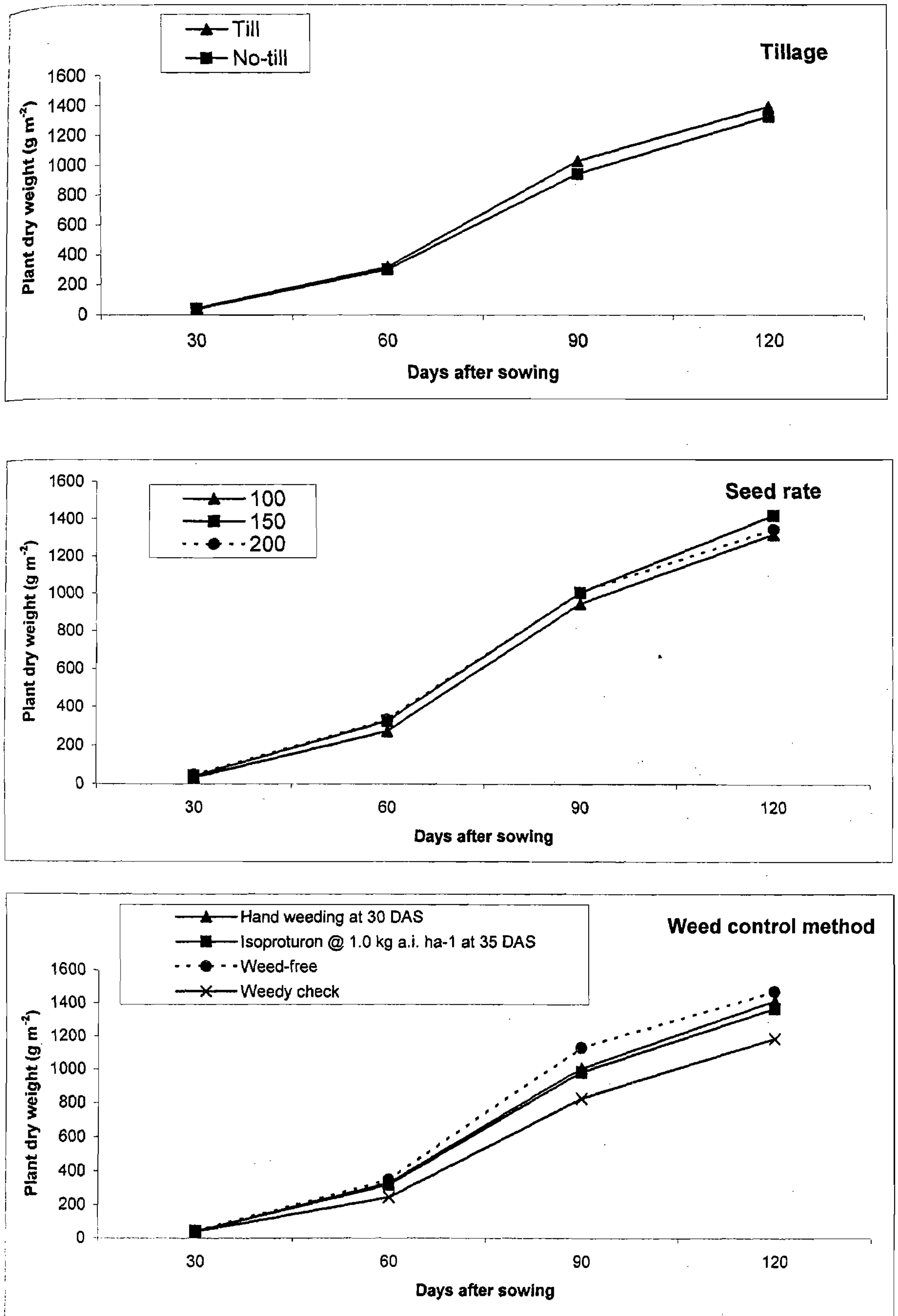


Fig. 4a: Plant dry weight (g m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages during 2002-03

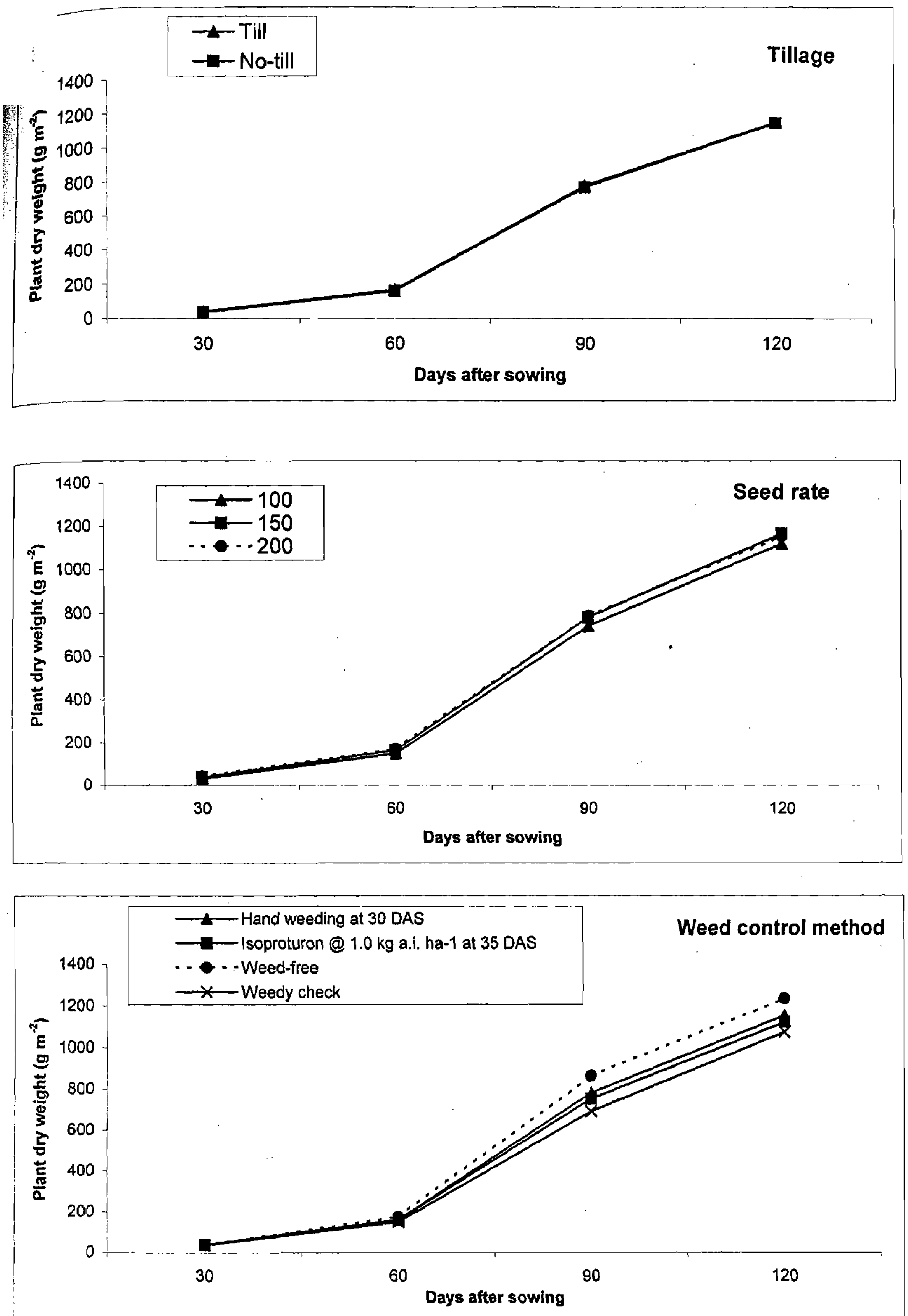


Fig. 4b: Plant dry weight (g m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages during 2003-04

noted with 200 kg seed rate was significantly higher than that of 100 kg seed rate at 60 DAS only during 2003-04.

All the weed control treatments resulted significantly higher plant dry weight as compared to weedy check at 60, 90 and 120 DAS during both the years except due to isoproturon at 120 DAS during 2003-04. Weed free treatment was significantly superior over isoproturon and weedy check at 60 and 90 DAS during both the years and 120 DAS during 2003-04. Similarly hand weeding and isoproturon being at par with each other were significantly superior over weedy check at 60, 90 and 120 DAS during 2002-03 and at 60 and 90 DAS during 2003-04.

4.1.6 Mean crop growth rate ($\overline{CGR}$)

Mean crop growth rate (g day^{-1}m^{-2}) increased with advancement of crop age upto 60-90 days period. Seed rate and weed control method resulted significant difference in $\overline{CGR}$ but tillage had not significant effect on $\overline{CGR}$ (Table 8 and Appendix-VIII).

Significantly higher $\overline{CGR}$ was noted with 200 and 150 kg seed rate over 100 kg seed rate at 30-60 days period during 2002-03 only.

Weed free treatment resulted significantly more $\overline{CGR}$ than other weed control treatments at 30-60 and 60-90 days period during both the years except over hand weeding at 30-60 days period during 2002-03. Hand weeding and isoproturon being at par with each other were significantly superior than weedy check at 30-60 days period during both the years. Further, hand weeding was

Table 8: **Mean crop growth rate (g day^{-1} m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Mean crop growth rate (g day^{-1} m^{-2})					
	Days stages					
	2002-03			2003-04		
	30-60	60-90	90-120	30-60	60-90	90-120
Tillage						
Till	9.18	23.63	12.14	4.19	20.32	12.34
No-till	8.84	21.34	12.81	4.12	20.23	12.59
S.Em.±	0.23	0.98	0.55	0.14	0.78	0.61
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Seed rate (kg ha^{-1})						
100	8.00	22.39	12.37	3.96	19.76	12.54
150	9.48	22.61	13.78	4.22	20.56	12.69
200	9.54	22.45	11.27	4.29	20.51	12.15
S.Em.±	0.28	1.21	0.67	0.17	0.96	0.75
CD (P=0.05)	0.88	NS	NS	NS	NS	NS
Weed control method						
Hand weeding at 30 DAS	9.73	22.38	13.72	4.10	20.64	12.44
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	9.22	22.10	12.87	4.10	19.64	12.29
Weed-free	10.28	26.09	11.31	4.64	22.84	12.40
Weedy check	6.79	19.38	12.00	3.78	17.98	12.72
S.Em.±	0.29	1.27	0.62	0.11	0.74	0.81
CD (P=0.05)	0.83	3.65	NS	0.31	2.11	NS

found significantly better than weedy check at 60-90 days period during 2003-04.

4.1.7 Mean relative growth rate ($\overline{\text{RGR}}$)

Significant differences in $\overline{\text{RGR}}$ ($g\ g^{-1} day^{-1} m^{-2}$) were recorded due to tillage, seed rate and weed control method (Table 9 and Appendix-IX).

Treatment of no-till resulted significantly higher $\overline{\text{RGR}}$ as compared to till at 30-60 days period during 2003-04 only.

Significantly higher $\overline{\text{RGR}}$ was noted with 100 kg seed rate than that of 200 kg seed rate at 30-60 days period during 2003-04 only. At 30-60 days stage weed free treatment resulted significant increase in $\overline{\text{RGR}}$ over isoproturon and weedy check during 2002-03 and it was superior overall other weed control treatments during 2003-04. Hand weeding also resulted significantly higher $\overline{\text{RGR}}$ than that of weedy check during both the years.

4.1.8 Root studies

4.1.8.1 Root length density

Root length density ($cm\ cm^{-3}$) was noted higher under till treatment than the no-till at all the soil depths during 2003-04 (Table 10 and Fig. 5a).

A progressive decrease in root length density was noted with increase in soil depth and it reached minimum at 50-60 cm depth under both the tillage treatments.

Table 9: **Mean relative growth rate (g g^{-1} day^{-1} m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Mean relative growth rate (g g^{-1} day^{-1} m^{-2})					
	Days stages					
	2002-03			2003-04		
	30-60	60-90	90-120	30-60	60-90	90-120
Tillage						
Till	0.0659	0.0391	0.0099	0.0474	0.0513	0.0129
No-till	0.0690	0.0380	0.0111	0.0512	0.0523	0.0134
S.Em.±	0.0011	0.0012	0.0016	0.0012	0.0014	0.0016
C.D. (P=0.05)	NS	NS	NS	0.0038	NS	NS
Seed rate (kg ha^{-1})						
100	0.0692	0.0414	0.0105	0.0532	0.0533	0.0136
150	0.0680	0.0375	0.0117	0.0487	0.0516	0.0132
200	0.0651	0.0369	0.0094	0.0461	0.0506	0.0126
S.Em.±	0.0014	0.0015	0.0020	0.0015	0.0017	0.0019
CD (P=0.05)	NS	NS	NS	0.0046	NS	NS
Weed control method						
Hand weeding at 30 DAS	0.0704	0.0368	0.0116	0.0497	0.0527	0.0127
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	0.0677	0.0376	0.0106	0.0482	0.0511	0.0132
Weed-free	0.0721	0.0392	0.0084	0.0527	0.0528	0.0119
Weedy check	0.0595	0.0407	0.0114	0.0467	0.0507	0.0146
S.Em.±	0.0014	0.0018	0.0018	0.0010	0.0012	0.0016
CD (P=0.05)	0.0041	NS	NS	0.0030	NS	NS

Table 10: Root length density (cm cm^{-3}) and root dry weight (mg) at 105 DAS as influenced by tillage at different soil depths

Soil depth (cm)	Root length density (cm cm^{-3})		Root dry weight (mg)	
	2003-04		2003-04	
	Till	No-till	Till	No-till
0-10	0.680	0.556	683	658
10-20	0.340	0.280	221	209
20-30	0.235	0.158	176	146
30-40	0.189	0.150	152	108
40-50	0.104	0.092	64	45
50-60	0.075	0.064	54	34

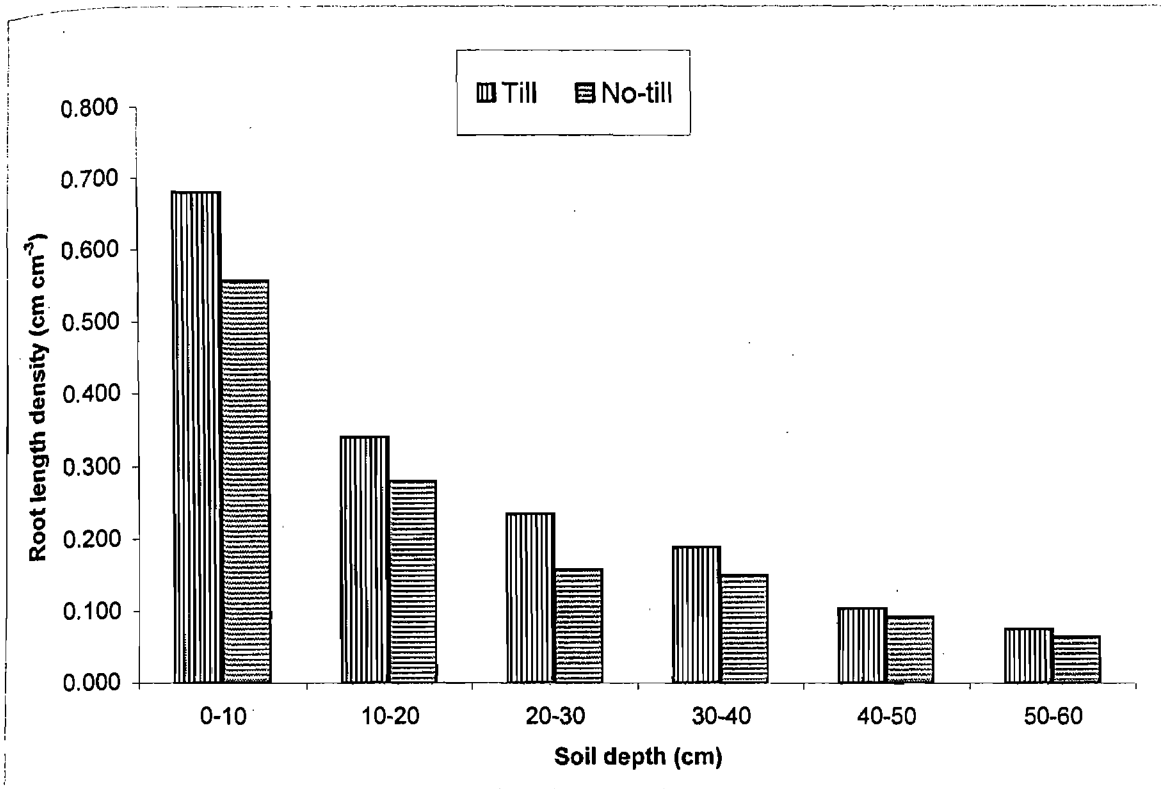


Fig.5a: Root length density (cm cm^{-3})at 105 DAS as influenced by tillage at different soil depths during 2003-04

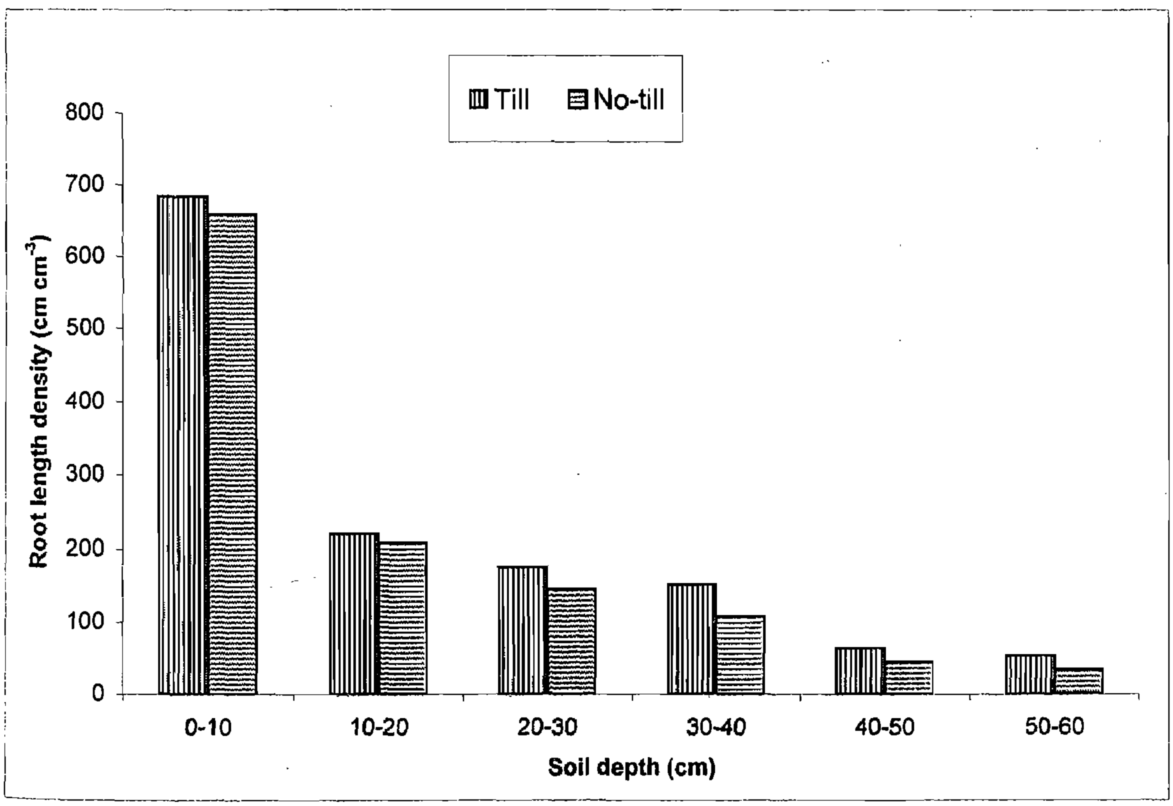


Fig.5b: Root dry weight(mg) at 105 DAS as influenced by tillage at different soil depths during 2003-04

4.1.8.2 Root dry weight

Higher root dry weight was noted with till treatment than that of no-till at all the soil depths during 2003-04 (Table 10 and Fig. 5b).

A progressive decrease in root dry weight was observed with increase in soil depth and it was minimum at 50-60 cm depth under both the tillage treatment.

4.1.9 Days taken to heading

Number of days taken to 50 per cent heading was more during 2002-03 than 2003-04. Number of days taken to heading differed significantly due to seed rate and weed control method. But tillage did not cause significant variation in days to heading (Table 11and Appendix-X).

Significantly more number of days for heading was noted under 100 kg over 150 and 200 kg seed rate during 2002-03 only.

Significantly more number of days for heading were noted with weed free than weedy check during both the years. Significantly more number days to heading was noted under hand weeding and isoproturon than weedy check during 2002-03 and 2003-04, respectively.

4.1.10 Days taken to maturity

Number of days taken to maturity was more during 2002-03 than 2003-04. Tillage, seed rate and weed control method caused significant variation in number of days taken to maturity (Table 11 and Appendix-X).

Table 11: **Development stages (days) as influenced by tillage, seed rate and weed control method**

Treatments	Development stages (days)					
	Heading		Maturity		Reproductive period	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
Till	94.5	83.4	140.6	117.2	46.1	33.7
No-till	93.9	82.9	143.5	119.0	49.6	36.1
S.Em.±	0.2	0.2	0.2	0.2	0.3	0.2
C.D. (P=0.05)	NS	NS	0.6	0.5	0.9	0.8
Seed rate (kg ha^{-1})						
100	94.9	83.5	143.6	119.2	48.7	35.7
150	94.0	83.0	141.9	117.9	47.8	34.9
200	93.7	83.1	140.7	117.2	46.9	34.1
S.Em.±	0.3	0.2	0.2	0.2	0.3	0.3
CD (P=0.05)	0.9	NS	0.7	0.7	1.1	0.9
Weed control method						
Hand weeding at 30 DAS	94.5	83.2	142.6	118.4	48.1	35.2
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	94.2	83.5	141.6	118.0	47.3	34.5
Weed-free	94.8	83.6	143.8	119.0	49.0	35.4
Weedy check	93.3	82.5	140.1	116.9	46.8	34.4
S.Em.±	0.4	0.3	0.2	0.2	0.4	0.3
CD (P=0.05)	1.0	0.9	0.6	0.6	1.1	1.0

Days taken to maturity were significantly more under no-till as compared to till treatment during both the years.

Number of days taken to maturity decreased with increase in seed rate. Significantly more number of days to maturity was noted with 100 kg than 150 and 200 kg seed rate during both the years. Further, number of days to maturity under 150 kg seed rate was significantly more than 200 kg seed rate during both the years.

All the weed control treatments resulted significantly more days to maturity over the weedy check during both the years. More days to maturity were noted under weed-free treatment which was significantly superior than all the weed control methods. Further, hand weeding followed by isoproturon were significantly superior than the weedy check.

4.1.11 Reproductive period

Reproductive period was more during 2002-03 as compared to 2003-04. Reproductive period differed significantly due to varied tillage, seed rate and weed control method (Table 11 and Appendix-X).

Significantly longer reproductive period was noted with no-till as compared to till treatment during both the years.

In general, reproductive period decreased with increase in seed rate. 100 kg seed rate resulted significantly longer reproductive period over 200 kg seed rate during both the years.

Significantly longer reproductive period was recorded with weed free treatment as compared to isoproturon during 2002-03 and weedy check during both the years. Hand weeding have significantly longer reproductive period over weedy check during 2002-03 only.

4.2 Yield and yield attributes

4.2.1 Number of spikes

Number of spike m^{-2} was more during 2002-03 than 2003-04. Tillage, seed rate and weed control method resulted significant variation in number of spikes m^{-2} during both the years (Table 12 and Appendix-XI).

Significantly more number of spikes was recorded under till treatment than no-till during both the years.

Significantly more number of spikes was noted with 200 and 150 kg seed rate being at par with each other over 100 kg seed rate during both the years.

Weed-free, hand weeding and isoproturon treatments, being at par resulted significantly more number of spikes over weedy check during both the years.

4.2.2 Spike length

More spike length (cm) was recorded during 2003-04 than 2002-03. Spike length did not differ significantly due to tillage and weed control method.

Table 12: Number of spikes (m^{-2}) as influenced by tillage, seed rate and weed control method

Treatments	Number of spikes (m^{-2})	
	2002-03	2003-04
Tillage		
Till	474	422
No-till	426	382
S.Em.±	10	10
C.D. (P=0.05)	30	32
Seed rate (kg ha^{-1})		
100	394	365
150	477	406
200	478	436
S.Em.±	12	12
CD (P=0.05)	37	39
Weed control method		
Hand weeding at 30 DAS	464	404
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	455	406
Weed-free	474	431
Weedy check	407	367
S.Em.±	16	11
CD (P=0.05)	46	33

But seed rate had significant difference on spike length during 2002-03 only (Table 13 and Appendix-XII).

Significantly more spike length was noted with 100 kg seed rate as compared to 150 and 200 kg seed rate during 2002-03 only.

4.2.3 Number of fertile spikelets

More fertile spikelets spike^{-1} were recorded during 2002-03 than 2003-04. Tillage resulted significant difference in fertile spikelets spike^{-1} during 2003-04 only. But seed rate and weed control method did not cause significant difference in fertile spikelets spike^{-1} (Table 13 and Appendix-XII).

Significantly higher number of fertile spikelets was noted with no-till than till treatment during 2003-04 only.

4.2.4 Number of sterile spikelets

Number of sterile spikelets spike^{-1} was higher during 2002-03 as compared to 2003-04. Sterile spikelets spike^{-1} did not differ significantly due to tillage, seed rate and method of weed control during both the years (Table 13 and Appendix-XII).

4.2.5 Number of grains

More number of grains spike^{-1} was recorded during 2002-03 than 2003-04. Tillage, seed rate and weed control method did not cause significant variation in number of grains spike^{-1} during both the years (Table 14 and Appendix-XIII).

Table 13: Spike length (cm), fertile spikelets spike^{-1} and sterile spikelets spike^{-1} as influenced by tillage, seed rate and weed control method

Treatments	Spike length (cm)		Fertile spikelets spike^{-1}		Sterile spikelets spike^{-1}	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
Till	11.20	11.32	18.48	13.46	4.48	2.48
No-till	11.27	11.80	18.57	14.76	4.44	2.57
S.Em.±	0.09	0.21	0.21	0.24	0.16	0.05
C.D. (P=0.05)	NS	NS	NS	0.77	NS	NS
Seed rate (kg ha^{-1})						
100	11.49	11.79	18.83	14.29	4.36	2.52
150	11.12	11.46	18.44	14.09	4.49	2.48
200	11.10	11.44	18.31	13.94	4.53	2.58
S.Em.±	0.11	0.25	0.26	0.30	0.20	0.07
CD (P=0.05)	0.35	NS	NS	NS	NS	NS
Weed control method						
Hand weeding at 30 DAS	11.21	11.56	18.49	14.13	4.54	2.70
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	11.23	11.56	18.57	14.26	4.18	2.34
Weed-free	11.33	11.64	18.69	14.30	4.41	2.56
Weedy check	11.18	11.48	18.36	13.74	4.71	2.51
S.Em.±	0.22	0.15	0.37	0.35	0.30	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS

4.2.6 Grain weight

More grain weight spike^{-1} (g) was recorded during 2002-03 as compared to 2003-04. Tillage and seed rate did not cause significant difference in grain weight spike^{-1}. But grain weight spike^{-1} differed significantly due to weed control method during 2003-04 (Table 14 and Appendix-XIII).

Weed free, hand weeding and isoproturon being at par resulted significantly more grain weight spike^{-1} as compared to weedy check during 2003-04.

4.2.7 1000-grain weight

Higher 1000-grain weight (g) was recorded during 2002-03 than 2003-04. Tillage, seed rate and weed control method did not have significant effect on 1000-grain weight (Table 14 and Appendix-XIII).

4.2.8 Biological yield

Biological yield (kg ha^{-1}) was higher during 2002-03 than 2003-04. Biological yield did not differ significantly due to tillage and seed rate, whereas method of weed control had significant effect on biological yield (Table 15 and Appendix-XIV).

All the weed control treatments resulted significantly higher biological yield as compared to weedy check during both the years. Biological yield recorded under weed free treatment was significantly higher than all other weed control methods during both the years. Further hand weeding and

Table 14: Number of grains $spike^{-1}$, grain weight $spike^{-1}$ (g) and 1000-grain weight (g) as influenced by tillage, seed rate and weed control method

Treatments	Number of grains $spike^{-1}$		Grain weight $spike^{-1}$ (g)		1000-grain weight (g)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
Till	43.03	39.72	1.81	1.74	42.73	42.17
No-till	44.28	40.68	1.90	1.83	43.71	43.26
S.Em.±	1.15	0.97	0.04	0.05	0.34	0.41
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Seed rate (kg ha^{-1})						
100	44.70	40.91	1.89	1.86	43.50	42.97
150	43.05	40.53	1.85	1.77	43.22	42.89
200	43.23	39.16	1.82	1.73	42.94	42.30
S.Em.±	1.41	1.19	0.05	0.06	0.42	0.50
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed control method						
Hand weeding at 30 DAS	43.44	40.61	1.88	1.82	43.45	43.02
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	44.98	41.12	1.86	1.82	43.38	42.70
Weed-free	44.71	41.40	1.91	1.87	43.40	43.17
Weedy check	41.50	37.67	1.77	1.64	42.65	41.99
S.Em.±	1.99	1.39	0.08	0.06	0.79	0.49
CD (P=0.05)	NS	NS	NS	0.17	NS	NS

isoproturon being at par with each other resulted significantly higher biological yield than weedy check during both the years.

4.2.9 Grain yield

Grain yield (kg ha^{-1}) was higher during 2002-03 as compared to 2003-04. Grain yield did not differ significantly due to tillage and seed rate, whereas weed control method had significant effect on grain yield (Table 15, Fig. 6 and Appendix-XIV).

All the weed control methods resulted significantly higher grain yield as compared to weedy check during both the years. Among different weed control methods significantly higher grain yield was noted with weed free treatment over all other weed control methods. Further, hand weeding followed by isoproturon were significantly superior over weedy check. However during 2002-03, differences between hand weeding and isoproturon was not significant.

4.2.10 Straw yield

Straw yield (kg ha^{-1}) was higher during 2002-03 than 2003-04. Tillage and seed rate did not cause significant difference in straw yield, whereas weed control method resulted significant difference in straw yield during 2003-04 (Table 15, Fig. 6 and Appendix-XIV).

Among all the weed control treatments, weed free resulted significantly higher straw yield over other weed control treatments during 2003-04 only.

Table 15: Biological yield (kg ha^{-1}), grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and grain-straw ratio as influenced by tillage, seed rate and weed control method

Treatments	Biological yield (kg ha^{-1})		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Grain-straw ratio	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage								
Till	14276	11488	5321	3755	8955	7733	0.600	0.487
No-till	14151	11442	5032	3561	9119	7881	0.557	0.456
S.Em.±	193	165	100	64	193	164	0.019	0.017
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Seed rate (kg ha^{-1})								
100	13985	11200	5052	3520	8932	7680	0.571	0.461
150	14360	11651	5263	3709	9097	7942	0.585	0.470
200	14296	11544	5214	3746	9082	7798	0.579	0.484
S.Em.±	236	202	123	79	236	201	0.023	0.021
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed control method								
Hand weeding at 30 DAS	14394	11536	5395	3830	8999	7706	0.608	0.502
Isoproturon @ 1.0 kg a.i. ha-1 at 35 DAS	14236	11214	5194	3635	9042	7579	0.581	0.483
Weed-free	15058	12376	5830	4150	9228	8226	0.637	0.508
Weedy check	13167	10735	4287	3018	8880	7717	0.489	0.394
S.Em.±	173	147	88	68	203	128	0.020	0.012
CD (P=0.05)	496	422	254	195	NS	366	0.058	0.034

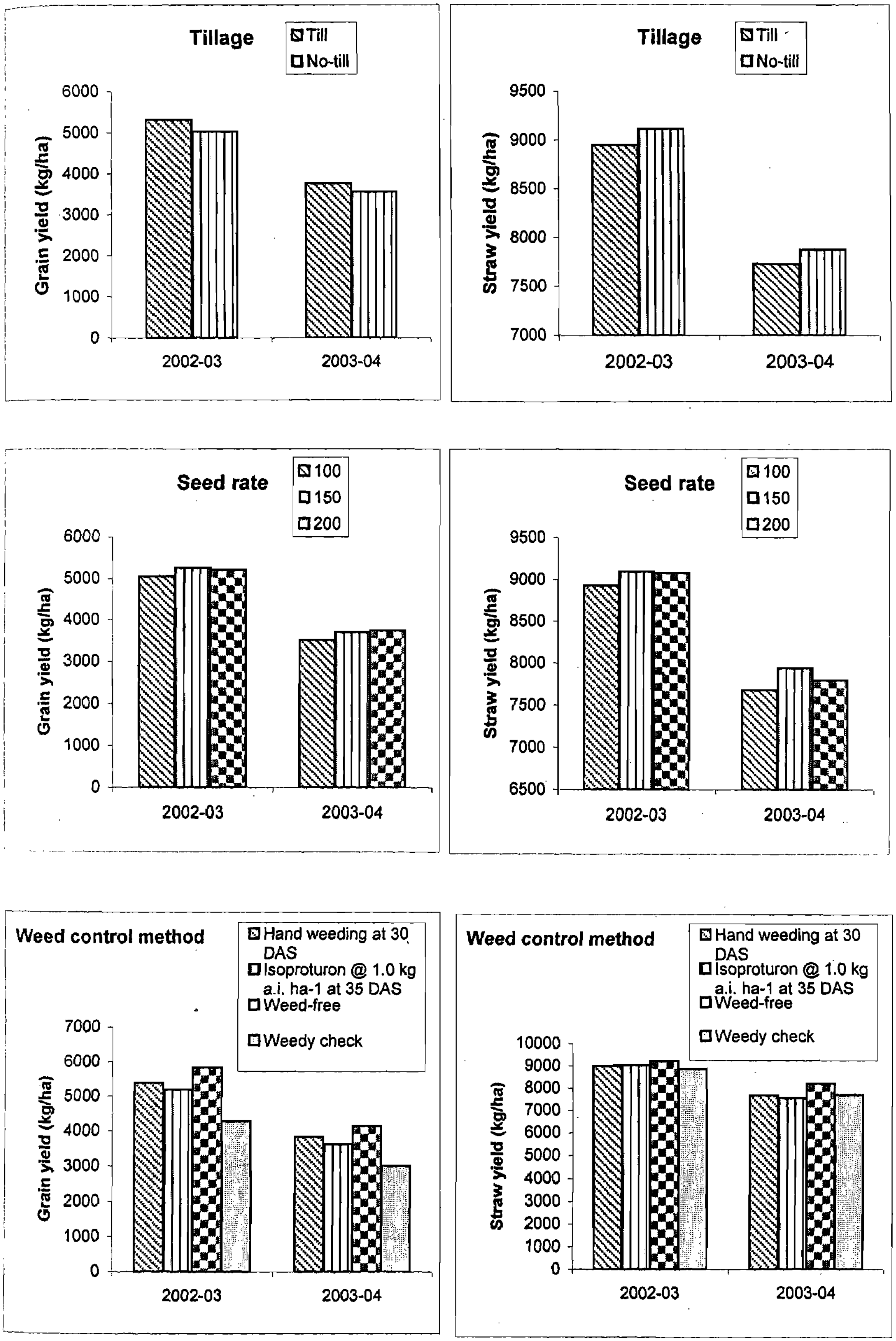


Fig. 6: Grain yield and straw yield (kg ha^{-1}) as influenced by tillage, seed rate and weed control method during both the years

4.2.11 Grain-straw ratio

Higher grain-straw ratio was recorded during 2002-03 than 2003-04. Grain-straw ratio differed significantly due to weed control method. But variation in tillage and seed rate did not cause significant variation in grain-straw ratio (Table 15 and Appendix-XIV).

Among all the weed control treatments, weed free, hand weeding and isoproturon being at par with each other resulted significantly higher grain-straw ratio than weedy check during both the years.

4.3 Weeds studies

4.3.1 Dominant weeds

Observations on dominant weeds on the experimental site was made time to time. Major weed species existed in experimental area were *Cynodon dactylon* (L.) Pers, *Cyperus rotundus* L, *Chenopodium album* L., *Anagallis arvensis* L., *Vicia sativa* L., *Coronopus didymus* L., *Circium arvense*, *Gnaphalium luteoalbum* L., *Medicago denticulata* Willd, *Fumeria parviflora* L., *Rumex acetosella* L., *Lineria minor* etc. (Table 16).

Non-grassy weeds dominated the grassy weeds as well as sedges. During 2003-04, infestation of *Phalaris minor* in the experimental area was also observed. *Cynodon dactylon* (L.) Pers., *Cirsium arvense, Rumex acetosella* L., *Eclipta alba* L., *Sorghum helepence, Parthenium hysterophorus*

Table 16: Weeds of experimental site during crop season

Botanical name	English name	Local name	Family
Grassy weeds			
Cynodon dactylon (L.) Pers.	Bermuda grass	Doob grass	Gramineae
Phalarish minor Retz.	Little grass, Canary grass	Gullidanda	Gramineae
Polypogon monspeliensis (L.) Desf.	Rabit foot grass, Beard grass	-----	Gramineae
Non-grassy weeds			
Chenopodium album L.	Lambs quarters	Bathua	Chenopodiaceae
Anagallis arvensis L.	Scarlet pimpernel	Krishna-neel	Primulaceae
Fumeria parviflora L.	Fumitory	Gajri, Bansoya	Fumariaceae
Lathyrus aphaca L.	Wild pea	Matri	Leguminaceae
Euphorbia hirta L.	Garden spurge	Bari dudhi	Euphorbiaceae
Medicago denticulate Willd	Yellow trefoil	Jangle jalebi	Leguminaceae
Oxalis corniculata L.	Creeping wood sorrel	Khattibuti	Oxalidaceae
Melilotus indica (L.) All	Yellow sweet clover	Pillisenji	Leguminaceae
Vicia sativa L.	Common vetch	Akra	Leguminaceae
Vicia hirsuta Koch.	Hairy tare	Misia	Leguminaceae
Coronopus didymus L.	Swin cress	Jangli baboon, Taratej	Crucifereae
Lineria minor	-----	------	------
Gnaphalium luteoalbum L	-----	------	------
Rumex acetosella L.	Red sorrel	Khatta palak	Polygonaceae
Spergula arvensis L.	Corn spurry	Bandhania	Caryophyllaceae
Solenum nigrum L.	------	Makoi	Solenaceae
Polygonum plebejum (Roth.) Hook	Indian knot-grass	Raniphul, Noni	Polygonaceae
Eclipta alba L.	Yerba-de-tago	Bhangra	Compositae
Sorghum halepence	Johnson grass	Basara	-----
Parthenium hysterophorus L.	Congress grass	Gajar ghass	-----
Circium arvence	Canada thistle	Kantaila	-----
Sedges			
Cyperus rotundus L.	Purple nutsedge	motha	Cyperaceae

L., *Euphorbia hirta* L. and *Gnaphalium luteoalbum* L. were found only under no-till plots.

4.3.2 Weed density

Higher weed density (no. m^{-2}) was note during 2002-03 as compared to 2003-04 at all the growth intervals except 60 DAS. Progressive decrease in weed density was noted with advancement of crop age which reached to minimum at maturity during both the years. Weed density differed significantly due to tillage, seed rate and weed control method (Table 17, Fig. 7a & 7b and Appendix-XV).

Significantly less weed density was recorded under no-till as compared to till treatment at 30 DAS during 2002-03 and 30 and 60 DAS during 2003-04. However, weed density noted under till plots was significantly lesser than no-till plots at 120 DAS during 2003-04.

Among seed rates less weed density was noted with 200 kg seed rate which was significantly lesser than at 100 kg seed rate at 90 DAS during 2002-03. While, at 120 DAS during 2003-04 significantly lesser weed density was noted with 200 kg seed rate as compared to 150 and 100 kg seed rate.

All the weed control treatments reduced weed density significantly as compared to weedy check at all the stages except at 30 DAS during both the years. At all the growth stages except 30 DAS lowest weed density was recorded under hand weeding which was significantly lesser than that of

Table 17: **Weed density (no. m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Weed density (no. m^{-2})							
	Days after sowing (DAS)							
	2002-03				2003-04			
	30	60	90	120	30	60	90	120
Tillage								
Till	4.64	4.03	3.89	3.31	4.56	4.13	3.76	2.63
	(368)	(215)	(160	(76)	(335)	(237)	(143)	(32)
No-till	4.27	3.90	3.86	3.45	4.23	3.94	3.76	3.02
	(231)	(162)	(149)	(91)	(217)	(168)	(135)	(52)
S.Em.±	0.04	0.06	0.05	0.08	0.04	0.05	0.08	0.05
C.D. (P=0.05)	0.12	NS	NS	NS	0.11	0.15	NS	0.16
Seed rate (kg ha^{-1})								
100	4.47	4.01	3.99	3.50	4.41	4.12	3.85	2.98
	(304)	(197)	(173)	(92)	(282)	(217)	(151)	(48)
150	4.44	3.98	3.87	3.40	4.39	4.04	3.78	2.86
	(298)	(189)	(154)	(84)	(276)	(203)	(142)	(43)
200	4.45	3.91	3.76	3.24	4.37	3.96	3.64	2.64
	(296)	(178)	(137)	(74)	(271)	(187)	(125)	(36)
S.Em.±	0.05	0.07	0.06	0.09	0.04	0.06	0.09	0.06
CD (P=0.05)	NS	NS	0.19	NS	NS	NS	NS	0.20
Weed control method								
Hand weeding at 30 DAS	5.93	4.59	4.63	3.97	5.87	4.72	4.38	3.06
	(393)	(104)	(109)	(59)	(371)	(118)	(89)	(23)
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	5.93	5.14	5.00	4.34	5.83	5.23	4.85	3.63
	(404)	(176)	(154)	(83)	(361)	(191)	(134)	(39)
Weed-free	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weedy check	5.94	6.13	5.86	5.23	5.86	6.19	5.80	4.61
	(400)	(473)	(355)	(192)	(372)	(501)	(334)	(106)
S.Em.±	0.06	0.06	0.06	0.10	0.06	0.04	0.07	0.06
CD (P=0.05)	0.17	0.17	0.16	0.28	0.19	0.13	0.19	0.17

Original values in parenthesis

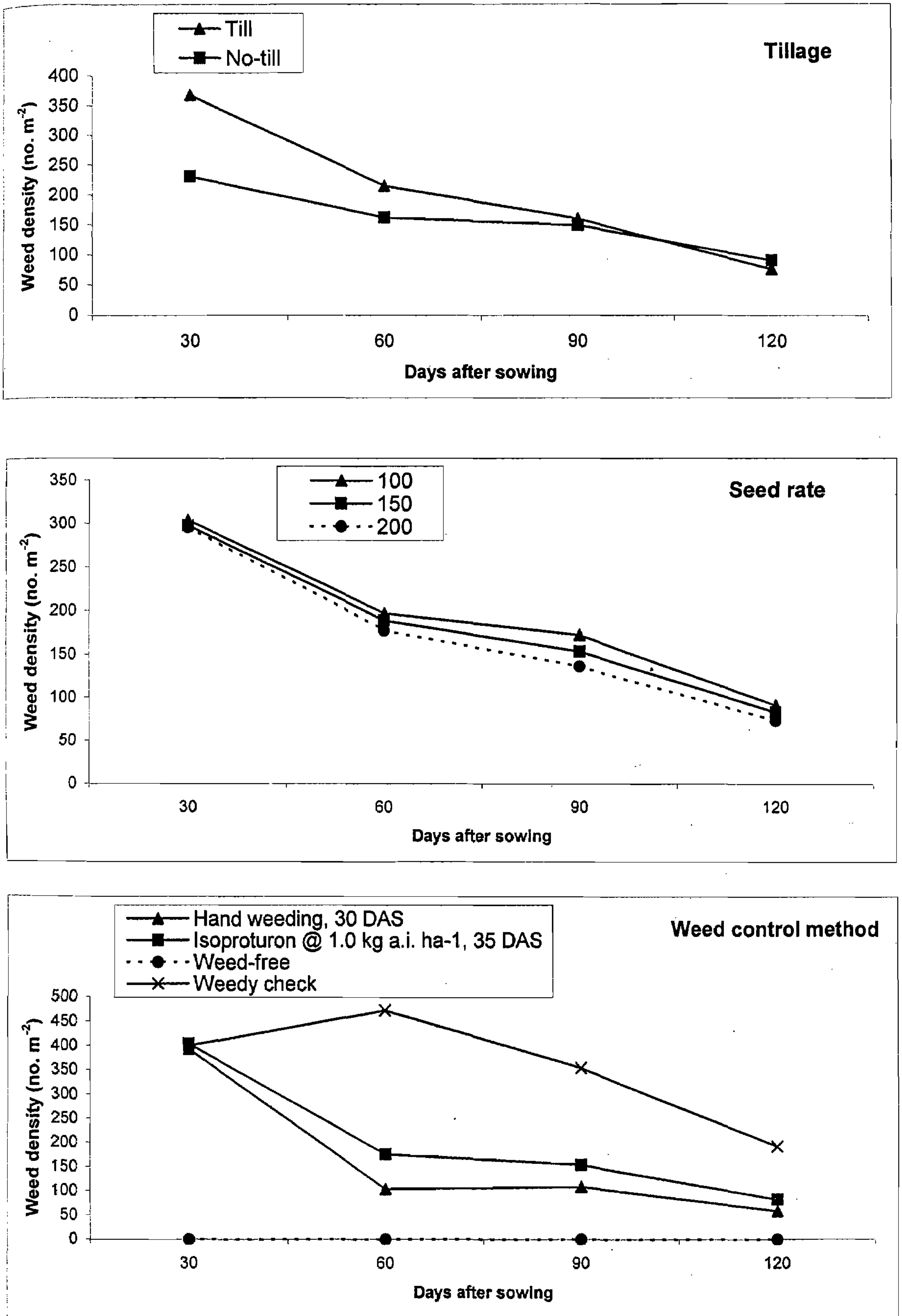
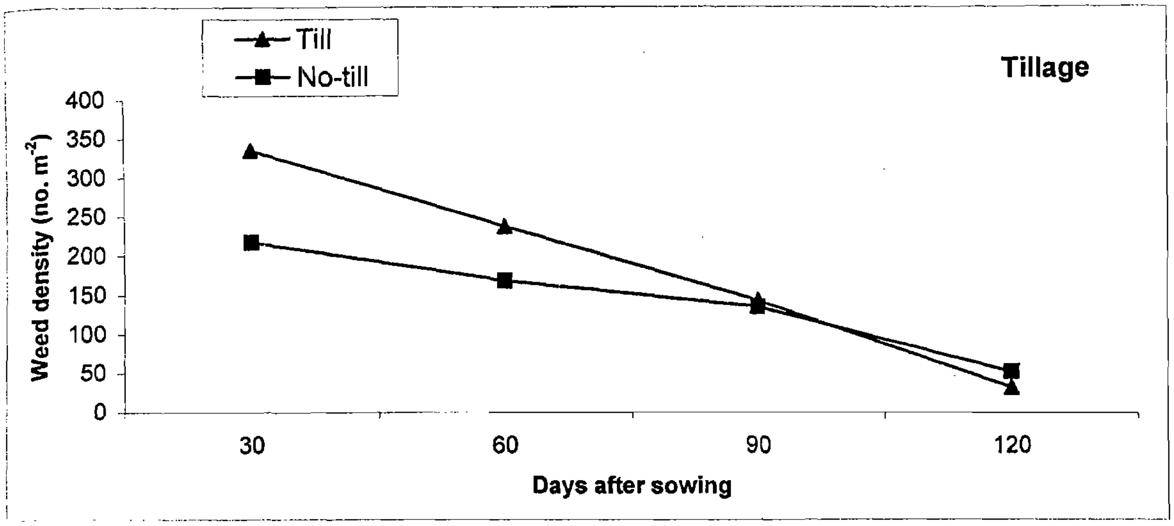
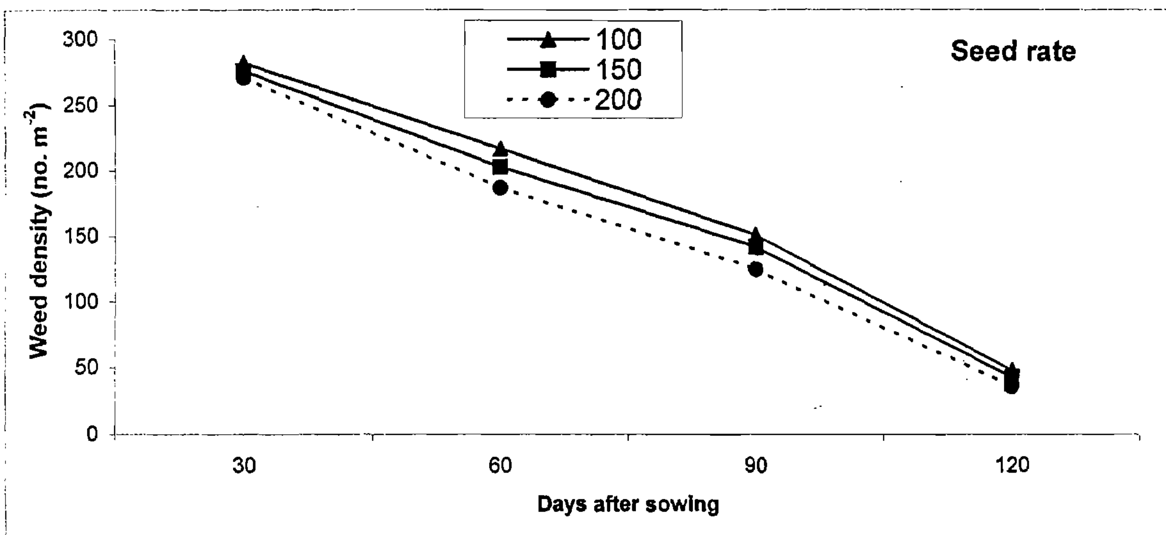


Fig. 7a: Weed density (no. m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages during 2002-03





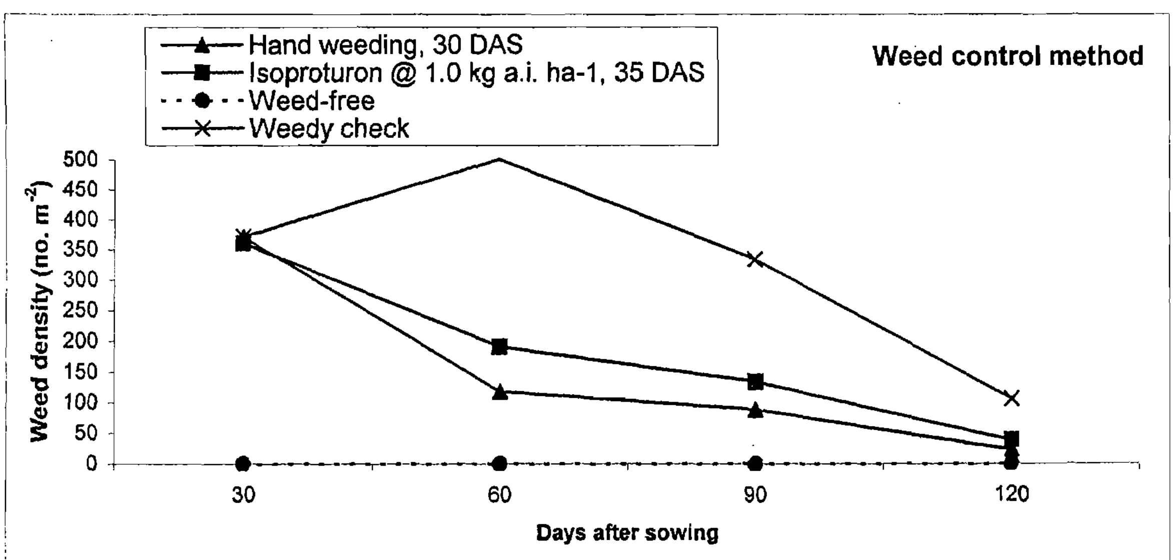


Fig. 7b: Weed density (no. m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages during 2003-04

isoproturon and weedy check during both the years. Further isoproturon resulted lesser significantly weed density than the weedy check.

Interaction between tillage and weed control method were found significant at 30 and 60 days stages during 2002-03 and all the growth stages during 2003-04 (Appendix-XXVI, XXVII, XXVIII and XXIX). Whereas during 2003-04 the interaction between seed rate and weed control method was found significant at 120 days only (Appendix-XXX).

4.3.3 Weed dry weight

Weed dry weight (g m^{-2}) was recorded higher during 2002-03 than 2003-04 at all the growth stages except at 30 DAS. A progressive increase in weed dry weight was observed with the advancement in crop age upto 90 DAS but later it decreased. Significant difference in weed dry weight due to varied tillage, seed rate and weed control method was noted (Table 18, Fig. 8a& 8b and Appendix-XVI).

Significantly lower weed dry weight was recorded due to till treatment than that of no-till at 30, 90 and 120 days during both the years. Whereas during 2002-03 at 60 days stage, significantly lesser weed dry weight was noted with no-till than till treatment.

Progressive decrease in weed dry weight was noted with every increment in seed rate during both the years. Significantly lesser weed dry weight was obtained at 200 kg than 150 and 100 kg seed rate at all the growth stages except 30 days during both the years. Whereas at 60 days stage 200 kg

Table 18: **Weed dry weight (gm^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Weed dry weight (g m^{-2}) Days after sowing (DAS) 2002-03 30	60	90	120	2003-04 30	60	90	120
Tillage								
Till	2.31 (15.7)	2.73 (45.5)	3.20 (65.2)	2.65 (32.2)	2.23 (14.1)	2.85 (49.5)	3.11 (60.8)	2.10 (17.9)
No-till	2.48 (19.9)	2.86 (43.0)	3.38 (81.5)	3.40 (87.1)	2.36 (16.8)	2.88 (43.9)	3.34 (78.6)	3.04 (59.7)
S.Em.±	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.03
C.D. (P=0.05)	0.07	0.05	0.08	0.07	0.09	NS	0.04	0.10
Seed rate (kg ha^{-1})								
100	2.42 (18.5)	2.87 (47.8)	3.36 (79.2)	3.09 (63.5)	2.32 (15.9)	2.95 (50.8)	3.30 (75.5)	2.69 (42.6)
150	2.40 (18.0)	2.81 (44.7)	3.31 (74.9)	3.04 (60.3)	2.31 (15.7)	2.87 (47.0)	3.25 (71.2)	2.58 (38.6)
200	2.35 (16.8)	2.71 (40.2)	3.20 (66.1)	2.95 (55.2)	2.26 (14.7)	2.78 (42.3)	3.12 (62.5)	2.46 (35.3)
S.Em.±	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.04
CD (P=0.05)	NS	0.06	0.09	0.08	NS	0.10	0.05	0.12
Weed control method								
Hand weeding at 30 DAS	3.21 (24.1)	2.77 (15.5)	3.69 (39.9)	3.19 (26.8)	3.03 (19.9)	2.93 (18.0)	3.52 (33.7)	2.38 (13.0)
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	3.17 (23.2)	3.58 (36.3)	4.27 (72.1)	4.03 (62.9)	3.09 (21.2)	3.68 (39.8)	4.21 (68.1)	3.39 (35.4_
Weed-free	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weedy check	3.19 (23.7)	4.82 (125.3)	5.20 (181.6)	4.89 (148.9)	3.06 (20.6)	4.85 (129.1)	5.17 (177.0)	4.52 (106.9)
S.Em.±	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.04
CD (P=0.05)	0.09	0.10	0.07	0.08	0.08	0.08	0.09	0.13

Original values in parenthesis

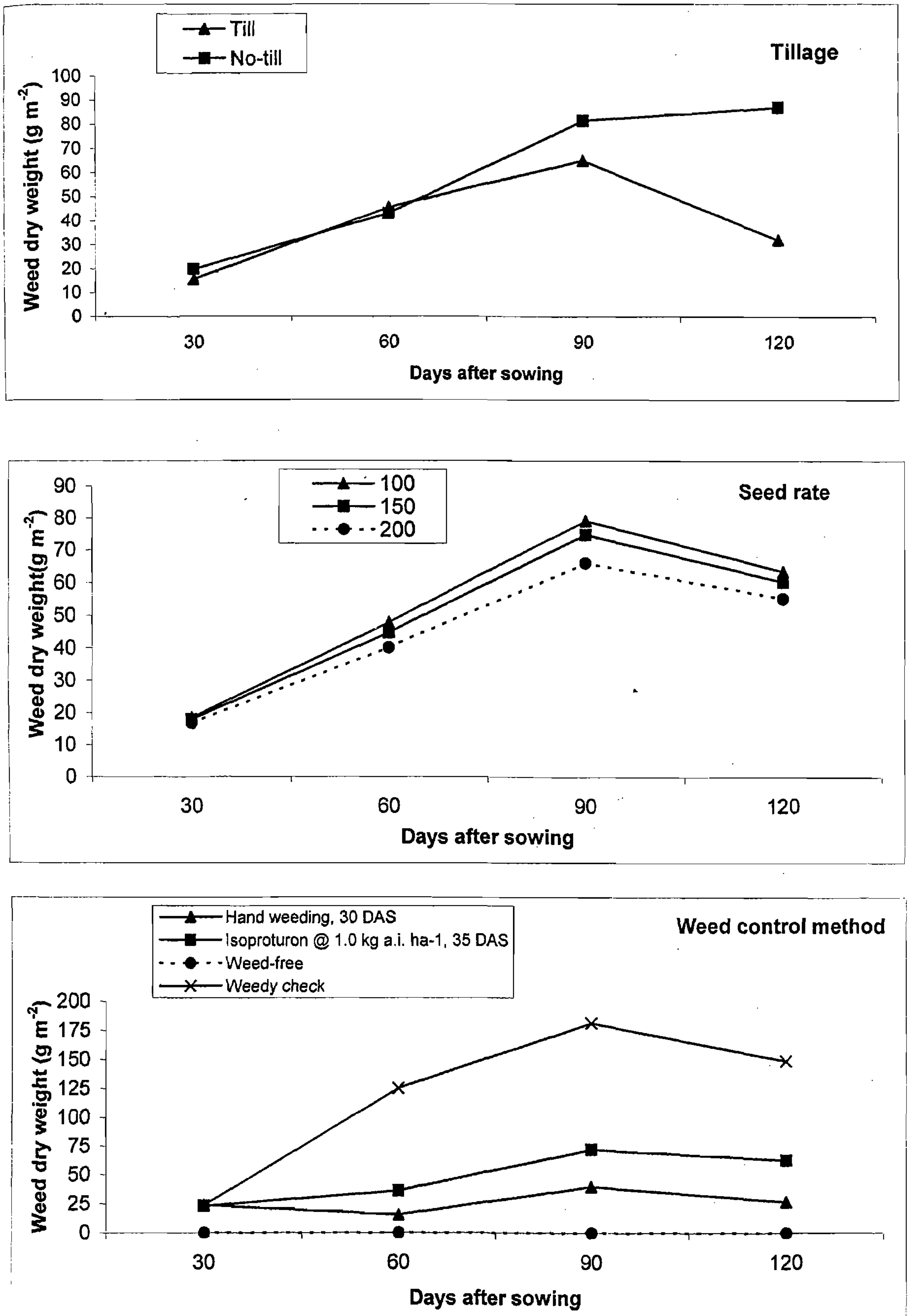


Fig. 8a: Weed dry weight (g m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages during 2002-03

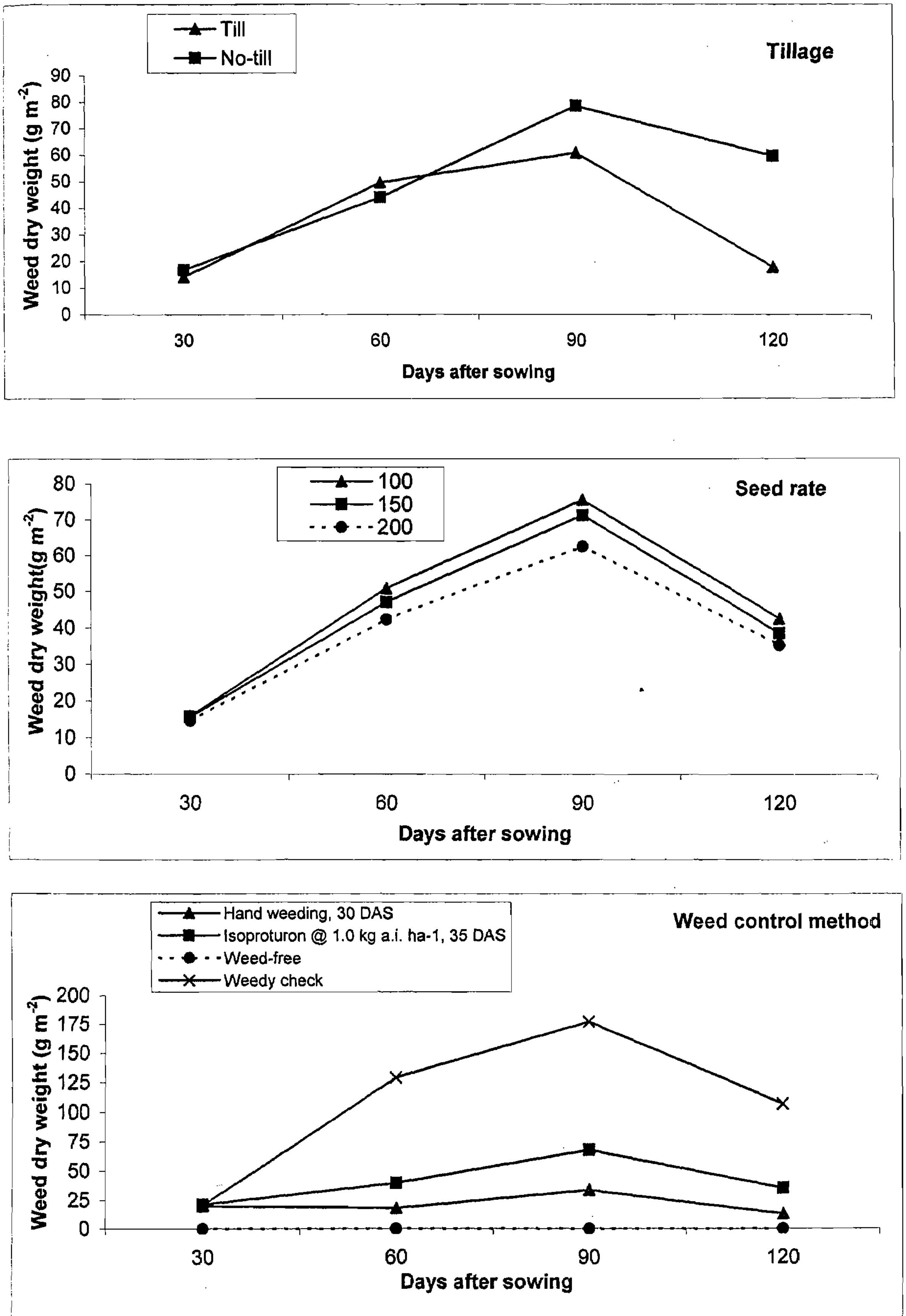


Fig. 8b: Weed dry weight (g m^{-2}) as influenced by tillage, seed rate and weed control method at different growth stages during 2003-04

seed rate had significantly lower weed dry weight than 100 kg seed rate during 2003-04.

All the weed control treatments reduced weed dry weight significantly than the weedy check at all the stages except 30 days during both the years. At 60, 90 and 120 days lower weed dry weight was recorded under hand weeding which was significantly lower than isoproturon and weedy check during both the years. All the weed control treatments have significant difference among themselves to each other at 60, 90 and 120 days stages during both the years.

Interaction effects between tillage and weed control method were found significant at all the growth stages during both the years (Appendix-XXXI, XXXII, XXXIII).

4.3.4 Weed control efficiency

Significant differences in weed control efficiency (%) were observed due to tillage and weed control method during both the years. But variation in seed rate did not cause significant variation in weed control efficiency (Table 19 and Appendix-XVII).

Significantly higher weed control efficiency was noted under till over no-till treatment at 60 DAS during both the years and only at 90 DAS during 2003-04.

At all the stages all the weed control treatments resulted significant increase in weed control efficiency over weedy check during both the years.

Table 19: **Weed control efficiency (%) as influenced by tillage, seed rate and weed control method at different growth stages**

Treatments	Weed control efficiency (%)					
	Days after sowing (DAS)					
	2002-03			2003-04		
	60	90	120	60	90	120
Tillage						
Till	68.6	60.4	60.6	66.5	62.1	65.5
No-till	60.7	59.0	59.7	60.3	59.9	63.4
S.Em.±	0.6	0.7	1.0	1.0	0.5	0.7
C.D. (P=0.05)	1.8	NS	NS	3.1	1.7	NS
Seed rate (kg ha^{-1})						
100	63.9	59.1	59.7	62.7	60.3	63.3
150	64.8	59.3	60.2	63.4	60.6	64.6
200	65.3	60.7	60.6	64.1	62.1	65.4
S.Em.±	0.7	0.8	1.2	1.2	0.7	0.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed control method						
Hand weeding at 30 DAS	89.0	78.2	82.3	85.7	81.7	89.3
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	69.6	60.6	58.3	67.8	62.3	68.5
Weed-free	100.0	100.0	100.0	100.0	100.0	100.0
Weedy check	0.0	0.0	0.0	0.0	0.0	0.0
S.Em.±	1.4	1.2	1.5	1.4	1.4	1.6
CD (P=0.05)	4.0	3.6	4.2	4.1	3.9	4.5

Maximum weed control efficiency was recorded under weed free followed by hand weeding and isoproturon in sequence at all the growth stages during both the years.

Interaction effects between tillage and weed control method was also found significant at 60 DAS during both the years (Appendix-XXXIV).

4.3.5 Crop weed competition index

Lesser crop weed competition index was recorded during 2002-03 than 2003-04 and it differed significantly due to different tillage, seed rate and weed control method (Table 20a, Fig. 9 and Appendix-XVIII).

Significantly lower crop weed competition was recorded under till than no till treatment during both the years.

Among different seed rates, lowest crop weed competition index was noted with 200 kg seed rate which was significantly lesser than that with 150 and 100 kg seed rate during 2002-03 and with 100 kg during 2003-04.

All the weed control treatments had significantly lower crop weed competition index as compared to weedy check. Significantly lesser crop weed competition was noted with hand weeding as compared to isoproturon and weedy check during both the years. Similarly isoproturon also resulted significant reduction than that of weedy check during both the years.

Interaction effects between tillage and weed control method were found significant during both the years (Table 20b).

Table 20a: Crop-weed competition index as influenced by tillage, seed rate and weed control method

Treatments	Crop-weed competition index	
	2002-03	2003-04
Tillage		
Till	10.1	9.0
No-till	12.3	14.5
S.Em.±	0.6	0.7
C.D. (P=0.05)	1.9	2.1
Seed rate (kg ha^{-1})		
100	12.8	13.9
150	11.0	11.5
200	9.9	9.8
S.Em.±	0.7	0.8
CD (P=0.05)	2.3	2.5
Weed control method		
Hand weeding at 30 DAS	7.5	7.6
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	10.9	12.3
Weed-free	0.0	0.0
Weedy check	26.4	27.2
S.Em.±	0.7	0.7
CD (P=0.05)	1.9	1.9

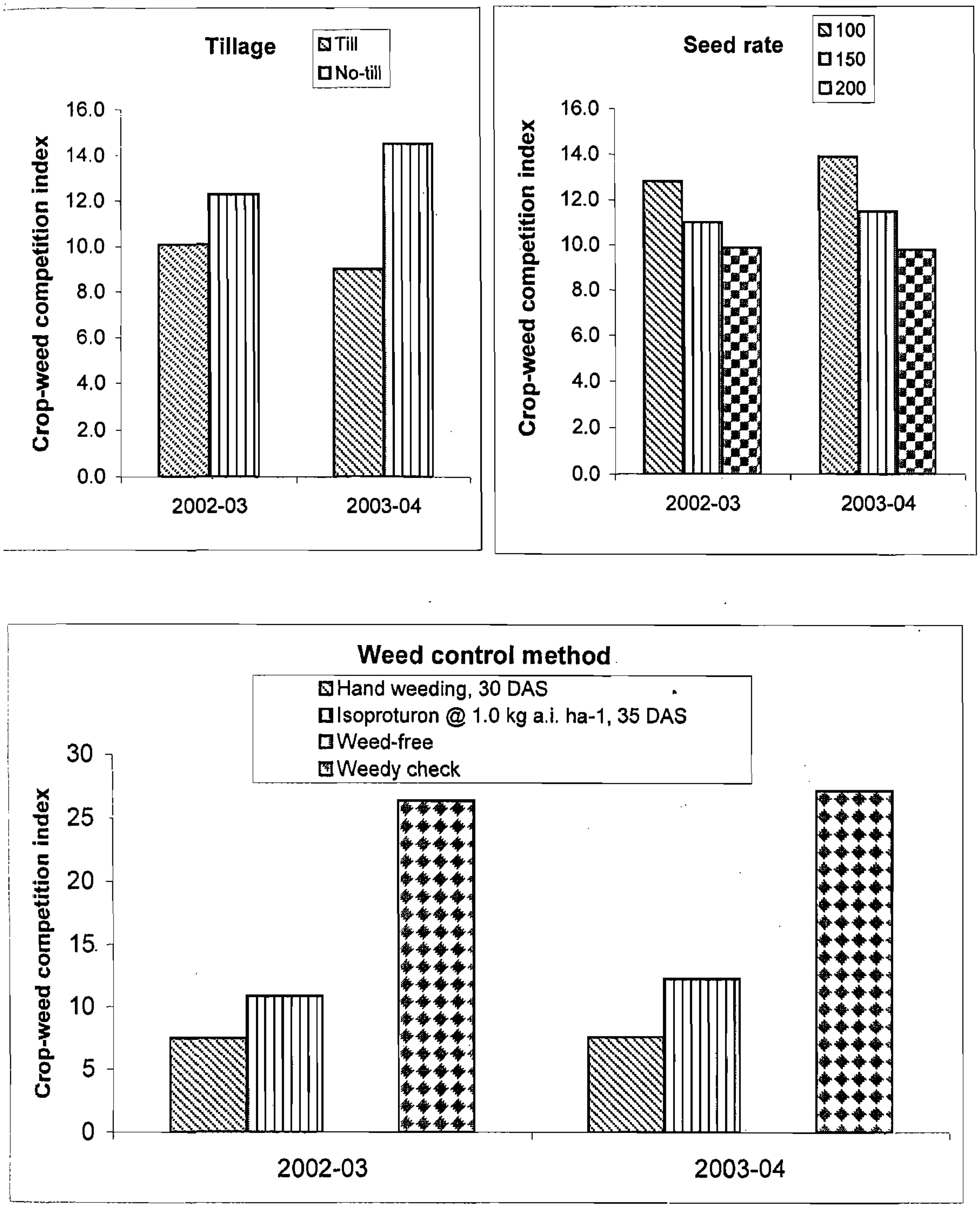


Fig. 9: Crop-weed competition index as influenced by tillage, seed rate and weed control method during both the years.

Table 20b: Interaction effect of tillage and weed control method on crop-weed competition index

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding, 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding, 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	6.5	8.3	0.0	25.8	5.9	9.1	0.0	21.1
No-till	8.6	13.6	0.0	27.0	9.2	15.5	0.0	33.3

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.9	0.9	2.7	2.7
For comparing two tillage at the same or different level of weed control method	1.0	1.1	3.0	3.1

The perusal of data indicated that among all the combination of tillage x weed control method lower crop-weed competition index was noted with hand weeding till treatment which was significantly minimum than the crop-weed competition index noted under isoproturon no-till, weedy till and no-till during 2002-03 and than all other treatment combination during 2003-04. Under weedy no-till treatment significantly higher crop-weed competition index was noted as compared to all other treatment combination.

4.4 Chemical studies

4.4.1 Nutrient content

4.4.1.1 Nitrogen content in grain

More nitrogen content (%) in grain was recorded during 2003-04 than 2002-03. Nitrogen content in grain differed significantly due to tillage and weed control method. But seed rate did not cause significant differences in nitrogen content during both the years (Table 21 and Appendix-XIX).

Significantly more nitrogen content in grain was recorded with no-till as compared to till treatment during both the years.

All the weed control treatments resulted significantly higher nitrogen content as compared to weedy check during both the years. Maximum nitrogen content was recorded with weed free treatment which was significantly more than that of all other weed control treatments during both the years. Further hand weeding and isoproturon being at par were significantly superior than weedy check during both the years.

4.4.1.2 Nitrogen content in straw

More nitrogen content (%) in straw was recorded during 2003-04 as compared to 2002-03. Tillage and weed control method caused significant differences in nitrogen content of straw during both the years, but seed rate had significant effect during 2003-04 only (Table 21 and Appendix-XIX).

Significantly more nitrogen content in straw was noted with no-till as compared to till treatment during both the years.

Nitrogen content with 100 kg seed rate was significantly more than that of 150 and 200 kg seed rate during 2003-04.

All the weed control treatments resulted significantly more nitrogen content in straw than weedy check during both the years. More nitrogen

Table 21: Nitrogen content (%) in grain and straw as influenced by tillage, seed rate and weed control method

Treatments	Nitrogen content (%)			
	Grain		Straw	
	2002-03	2003-04	2002-03	2003-04
Tillage				
Till	1.46	1.56	0.479	0.500
No-till	1.65	1.71	0.513	0.525
S.Em.±	0.05	0.04	0.010	0.005
C.D. (P=0.05)	0.16	0.13	0.030	0.015
Seed rate (kg ha^{-1})				
100	1.66	1.73	0.514	0.531
150	1.53	1.62	0.492	0.507
200	1.47	1.56	0.482	0.500
S.Em.±	0.06	0.05	0.012	0.006
CD (P=0.05)	NS	NS	NS	0.019
Weed control method				
Hand weeding at 30 DAS	1.60	1.68	0.523	0.539
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	1.56	1.64	0.517	0.534
Weed-free	1.71	1.79	0.536	0.553
Weedy check	1.35	1.43	0.407	0.425
S.Em.±	0.04	0.04	0.005	0.004
CD (P=0.05)	0.12	0.10	0.015	0.013

content was recorded due to weed free treatment, which was significantly higher than that of nitrogen content noted due to isoproturon and weedy check during 2002-03 and than all other weed control treatments during 2003-04. Further hand weeding and isoproturon being at par were significantly superior than weedy check during both the years.

4.4.1.3 Phosphorus content in grain

Higher phosphorus content (%) in grain was recorded during 2003-04 than 2002-03. Phosphorus content differed significantly due to different tillage, seed rate and weed control method (Table 22 and Appendix-XX).

Significantly higher phosphorus content in grain was recorded due to no-till than till treatment during both the years.

Phosphorus content in grain decreased with increasing seed rate during both the years. Significantly higher phosphorus content was noted with 100 kg seed rate as compared to 150 and 200 kg seed rate during both the years.

All the weed control treatments resulted significantly higher phosphorus content in grain as compared to weedy check during both the years. Weed free, hand weeding and isoproturon all being at par noted significantly higher phosphorus content in grain as compared to weedy check during both the years.

4.4.1.4 Phosphorus content in straw

Higher phosphorus content (%) in straw was recorded during 2003-04 than 2002-03. Phosphorus content differed significantly due to different tillage, seed rate and weed control method (Table 22 and Appendix-XX).

Table 22: Phosphorus content (%) in grain and straw as influenced by tillage, seed rate and weed control method

Treatments	Phosphorus content (%)			
	Grain		Straw	
	2002-03	2003-04	2002-03	2003-04
Tillage				
Till	0.275	0.277	0.0631	0.0653
No-till	0.282	0.283	0.0663	0.0681
S.Em.±	0.001	0.001	0.0006	0.0007
C.D. (P=0.05)	0.004	0.004	0.0018	0.0023
Seed rate (kg ha^{-1})				
100	0.284	0.287	0.0667	0.0696
150	0.278	0.279	0.0643	0.0660
200	0.274	0.275	0.0630	0.0646
S.Em.±	0.002	0.002	0.0007	0.0009
CD (P=0.05)	0.005	0.005	0.0022	0.0028
Weed control method				
Hand weeding at 30 DAS	0.281	0.282	0.0654	0.0680
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	0.280	0.282	0.0644	0.0668
Weed-free	0.284	0.285	0.0685	0.0701
Weedy check	0.270	0.271	0.0603	0.0619
S.Em.±	0.003	0.002	0.0007	0.0009
CD (P=0.05)	0.008	0.005	0.0019	0.0025

Significantly higher phosphorus content in straw was recorded with no-till than till treatment during both the years.

Phosphorus content in straw decreased with increase in seed rate. Significantly higher phosphorus content was noted with 100 kg seed rate than that of 150 and 200 kg seed rate during both the years.

All the weed control treatments resulted significantly more phosphorus content in straw than weedy check during both the years. Similarly more phosphorus content recorded with weed-free treatment which was significantly higher than that of isoproturon and weedy check during 2003-04 and all other weed control treatments during 2002-03. Further hand weeding and isoproturon were at par but significantly superior over weedy check during both the years.

4.4.1.5 Potassium content in grain

Potassium content (%) in grain was recorded more during 2003-04 than 2002-03. Tillage, seed rate and weed control method did not cause significant differences in potassium content of grain (Table 23 and Appendix-XXI).

4.4.1.6 Potassium content in straw

More potassium content (%) in straw was noted during 2003-04 than 2002-03. Tillage and seed rate did not cause significant variation in potassium content. But due to weed control method potassium content differed significantly (Table 23 and Appendix-XXI).

All the weed control treatments resulted significantly higher potassium content in straw as compared to weedy check during both the years. Potassium

Table 23: Potassium content (%) in grain and straw as influenced by tillage, seed rate and weed control method

Treatments	Potassium content (%)			
	Grain		Straw	
	2002-03	2003-04	2002-03	2003-04
Tillage				
Till	0.540	0.552	1.684	1.716
No-till	0.533	0.542	1.635	1.650
S.Em.±	0.007	0.006	0.031	0.021
C.D. (P=0.05)	NS	NS	NS	NS
Seed rate (kg ha^{-1})				
100	0.541	0.552	1.704	1.729
150	0.536	0.546	1.650	1.669
200	0.533	0.543	1.624	1.651
S.Em.±	0.009	0.007	0.037	0.026
CD (P=0.05)	NS	NS	NS	NS
Weed control method				
Hand weeding at 30 DAS	0.538	0.549	1.683	1.708
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	0.536	0.546	1.654	1.683
Weed-free	0.542	0.553	1.739	1.761
Weedy check	0.532	0.539	1.561	1.579
S.Em.±	0.005	0.005	0.027	0.019
CD (P=0.05)	NS	NS	0.078	0.055

content in straw recorded with weed free treatment which was significantly higher than that of isoproturon and weedy check during both the years. Further hand-weeding and isoproturon being at par with each other were significantly superior over weedy check during both the years.

4.4.2 Nutrient uptake by wheat

4.4.2.1 Nitrogen

Nitrogen uptake (kg ha^{-1}) by wheat crop was more during 2002-03 than 2003-04. Nitrogen uptake differed significantly due to weed control method, but tillage and seed rate did not cause significant differences in nitrogen uptake (Table 24 and Appendix-XXII).

All the weed control treatments resulted significantly more nitrogen uptake than weedy check during both the years. Nitrogen uptake recorded with weed-free treatment was significantly higher than all other weed control treatments during both the years. Hand weeding and isoproturon being at par during 2002-03 were significantly superior than weedy check during both the years.

4.4.2.2 Phosphorus

Phosphorus uptake (kg ha^{-1}) by wheat crop was higher during 2002-03 than 2003-04. Tillage and seed rate did not differ significantly as regards to phosphorus uptake but weed control method resulted significant difference in phosphorus uptake (Table 24 and Appendix-XXII).

Table 24: Nitrogen, phosphorus and potassium uptake (kg ha^{-1}) by wheat at harvest as influenced by tillage, seed rate and weed control method

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
Till	105.7	85.5	17.70	13.52	160.5	137.3
No-till	114.6	90.4	17.69	13.54	157.4	133.8
S.Em.±	3.1	1.7	0.16	0.12	3.7	2.9
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Seed rate (kg ha^{-1})						
100	114.4	89.6	17.76	13.54	160.6	136.3
150	110.2	88.3	17.87	13.62	159.3	136.8
200	105.9	85.8	17.46	13.41	156.9	133.5
S.Em.±	3.8	2.1	0.20	0.15	4.5	3.5
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed control method						
Hand weeding at 30 DAS	116.4	92.7	18.32	14.02	160.9	136.4
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	111.9	87.7	17.75	13.37	158.8	132.0
Weed-free	130.0	104.6	19.94	15.38	171.9	150.3
Weedy check	82.2	66.6	14.77	11.34	144.1	123.5
S.Em.±	2.3	1.5	0.19	0.14	3.1	2.3
CD (P=0.05)	6.5	4.2	0.56	0.41	9.0	6.7

All the weed control treatments resulted significantly higher phosphorus uptake than weedy check during both the years. Maximum phosphorus uptake were recorded under weed-free treatment followed by hand weeding and isoproturon in sequence during both the years. However, significant variations in phosphorus uptake were found among all weed control treatments with each other during both the years.

4.4.2.3 Potassium

More potassium uptake (kg ha^{-1}) by wheat crop was recorded during 2002-03 than 2003-04. Potassium uptake did not differ significantly due to tillage and seed rate. But weed control method had significant effect on potassium uptake (Table 24 and Appendix-XXII).

All the weed control methods resulted significantly higher potassium uptake over weedy check during both the years. Significantly maximum potassium uptake was recorded with weed-free treatment over all other weed control treatments during both the years. Hand weeding and isoproturon being at par with each other were noted significantly superior than that of weedy check during both the years.

4.4.3 Nutrient removals by weeds

4.4.3.1 Nitrogen

Lower nitrogen removal (kg ha^{-1}) by weeds at 60 DAS was observed during 2002-03 than 2003-04. Nitrogen removal by weeds did not differ significantly due to tillage. But seed rate and weed control method caused significantly difference in nitrogen removal by weeds (Table 25 and Appendix-XXIII).

Significantly lower nitrogen removal by weeds was observed due to 200 kg than 100 kg seed rate during both the years.

All the weed control treatments resulted significantly lower nitrogen removal by weeds as compared to weedy check. Significantly lesser nitrogen removal was noted with hand weeding as compared to isoproturon and weedy check during both the years. Further isoproturon was significantly superior than weedy check during both the years. Interaction effects between tillage and weed control method were recorded significant during both the years (Appendix-XXXV).

4.4.3.2 Phosphorus

Lower phosphorus removal (kg ha^{-1}) by weeds at 60 DAS was recorded during 2002-03 as compared to 2003-04. Tillage did not cause significant difference in phosphorus removal by weeds. But due to seed rate and weed control method phosphorus removal differed significantly (Table 25 and Appendix-XXIII).

Phosphorus removal by weeds decreased with increase in seed rate. Significantly lesser phosphorus was removed by weeds with 200 kg than 100 kg seed rate at 60 DAS during both the years.

All the weed control treatments resulted significantly lesser phosphorus removal by weeds as compared to weedy check during both the years. Significantly lesser phosphorus removal by weeds was also observed with hand weeding which was significantly superior than isoproturon and weedy check during both the years. Further isoproturon was significantly superior over weedy check during both the years.

Interaction effects between tillage and weed control method were found significant during both the years (Appendix-XXXVI).

4.4.3.3 Potassium

Less amount of potassium (kg ha^{-1}) was removed by weeds at 60 DAS during 2002-03 as compared to 2003-04. Potassium removal by weeds differed significantly due to varied seed rate and weed control method. But tillage did not affect potassium removal by weeds significantly (Table 25 and Appendix-XXIII).

Every increment in seed rate from 100 to 150 and 150 to 200 kg decreased potassium removed by weeds during both the years. Potassium removal by weeds was significantly lesser with 200 kg seed rate than that of 100 kg seed rate during both the years.

All the weed control treatments resulted significantly lesser removal of potassium by weeds than weedy check during both the years. Significantly lesser potassium removal by weeds was observed with hand weeding than

Table 25: Nitrogen, phosphorus and potassium removal (kg ha^{-1}) by weeds at 60 DAS as influenced by tillage, seed rate and weed control method

Treatments	Nitrogen removal (kg ha^{-1})		Phosphorus removal (kg ha^{-1})		Potassium removal (kg ha^{-1})	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage						
Till	7.81	8.52	2.60	2.83	8.89	9.69
No-till	7.46	7.62	2.46	2.51	8.48	8.65
S.Em.±	0.27	0.32	0.09	0.11	0.31	0.36
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Seed rate (kg ha^{-1})						
100	8.26	8.78	2.73	2.90	9.39	9.98
150	7.72	8.12	2.56	2.69	8.78	9.23
200	6.93	7.30	2.30	2.42	7.89	8.30
S.Em.±	0.33	0.39	0.11	0.13	0.38	0.44
CD (P=0.05)	1.05	1.22	0.35	0.41	1.20	1.39
Weed control method						
Hand weeding at 30 DAS	2.85	3.31	0.90	1.05	3.16	3.67
Isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS	6.53	7.16	2.10	2.30	7.39	8.11
Weed-free	0.00	0.00	0.00	0.00	0.00	0.00
Weedy check	21.17	21.81	7.12	7.33	24.18	24.91
S.Em.±	0.45	0.43	0.15	0.14	0.51	0.49
CD (P=0.05)	1.28	1.23	0.43	0.41	1.46	1.40

isoproturon and weedy check during both the years. So also isoproturon was significantly superior over weedy check during both the years.

Interaction effects between tillage and weed control method were found significant during both the years (Appendix-XXXVII).

4.5 Economic studies

4.5.1 Cost of cultivation

Lesser cost of cultivation (Rs.ha^{-1}) was recorded during 2002-03 as compared to 2003-04. Lesser cost of cultivation was noted due to no-till over till treatment during both the years. Low cost of cultivation was obtained with 100 kg seed rate and increase in seed rate upto 200 kg, cost of cultivation also increased. Minimum cost of cultivation was recorded under weedy check followed by isoproturon, hand weeding and weed-free treatment during both the years (Table 26, Fig. 10 and Appendix-XXIV, XXVa, XXVb, XXVc and XXXVd).

4.5.2 Gross return

Higher gross return (Rs.ha^{-1}) was recorded during 2002-03 than 2003-04. Tillage and seed rate caused significant difference in gross return during 2003-04, but various weed control methods had significant effect on gross return during both the years (Table 26 and Appendix-XXIV).

Significantly higher gross return was noted with till as compared no-till treatment during 2003-04. Gross return noted with 150 and 200 kg seed rate being at par was significantly higher than 100 kg seed rate during 2003-04 only.

All the weed control treatments required significant increase in gross return over the weedy check during both the years. Significantly higher gross return was recorded under weed free treatment over all other weed control treatments during both the years. Further hand weeding followed by isoproturon were significantly superior over weedy check during both the years.

Significant interaction effects were noted between tillage and weed control method during 2003-04 only (Appendix-XXXVIII). Significant differences were noted among all the weed control treatments with each other during both the years.

4.5.3 Net return

Higher net return (Rs. ha^{-1}) was noted during 2002-03 than 2003-04. Net return did not differ significantly due to tillage and seed rate treatments. But weed control method caused significant difference in net return (Table 26, Fig. 11 and Appendix-XXIV).

All the weed control treatments resulted significantly higher net return than weedy check during both the years. Net return recorded with weed-free treatment, was significantly higher than all other weed control treatments during both the years. Further, hand-weeding and isoproturon being at par with each other were significantly superior than that of weedy check during both the years.

Significant interaction effects between tillage and weed control method were found during 2003-04 only (Appendix-XXXIX).

4.5.4 Net return per rupee invested

Higher net return per rupee invested (Rs.) was observed during 2002-03 than 2003-04. Significant differences in net return per rupee invested were noted due to tillage, seed rate and weed control method (Table 26, Fig. 12 and Appendix-XXIV).

Significantly higher net return per rupee invested was observed with no-till treatment than that of till treatment during both the years.

Among different seed rates, higher net return per rupee invested was noted with 100 and 150 kg seed rate, as compared to 200 kg seed rate during both the years.

All the weed control treatments resulted significantly more net return per rupee invested as compared to weedy check during both the years. During 2002-03 significantly higher net return per rupee invested was found with isoproturon treatment followed by hand-weeding and weed-free treatments in sequence over weedy check. However during 2003-04, significantly higher net return per rupee invested was recorded with isoproturon, hand-weeding and weed-free being at par among themselves, were significantly better than weedy check.

Interaction effects between tillage and weed control method were noted significant during 2003-04 only (Appendix-XXXX).

Table 26: Cost of cultivation (Rs.ha^{-1}), gross return (Rs.ha^{-1}), net return (Rs.ha^{-1}) and net return per rupee invested (Rs.) as influenced by tillage, seed rate and weed control method

Treatments	Cost of cultivation (Rs.ha^{-1})		Gross return (Rs.ha^{-1})		Net return (Rs.ha^{-1})		Net return per rupee invested (Rs.)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Tillage								
Till	16139	18046	49641	37578	33503	19532	2.08	1.08
No-till	14559	16466	48115	36622	33557	20156	2.31	1.22
S.Em.±	-	-	506	268	506	268	0.03	0.01
C.D. (P=0.05)	-	-	NS	845	NS	NS	0.11	0.05
Seed rate (kg ha^{-1})								
100	14674	16256	47907	36001	33234	19745	2.27	1.21
150	15349	17256	49532	37662	34183	20407	2.23	1.19
200	16024	18256	49196	37636	33172	19381	2.08	1.06
S.Em.±	-	-	620	328	620	328	0.04	0.02
CD (P=0.05)	-	-	NS	1034	NS	NS	0.13	0.06
Weed control method								
Hand weeding at 30 DAS	15541	17448	50186	37998	34645	20550	2.24	1.19
Isoproturon @ 1.0 kg a.i. ha-1 at 35 DAS	14771	16678	48997	36544	34226	19866	2.33	1.20
Weed-free	16991	18898	53339	40952	36348	22054	2.15	1.17
Weedy check	14091	15998	42991	32904	28900	16906	2.06	1.06
S.Em.±	-	-	340	273	340	273	0.02	0.02
CD (P=0.05)	-	-	974	783	974	783	0.06	0.05

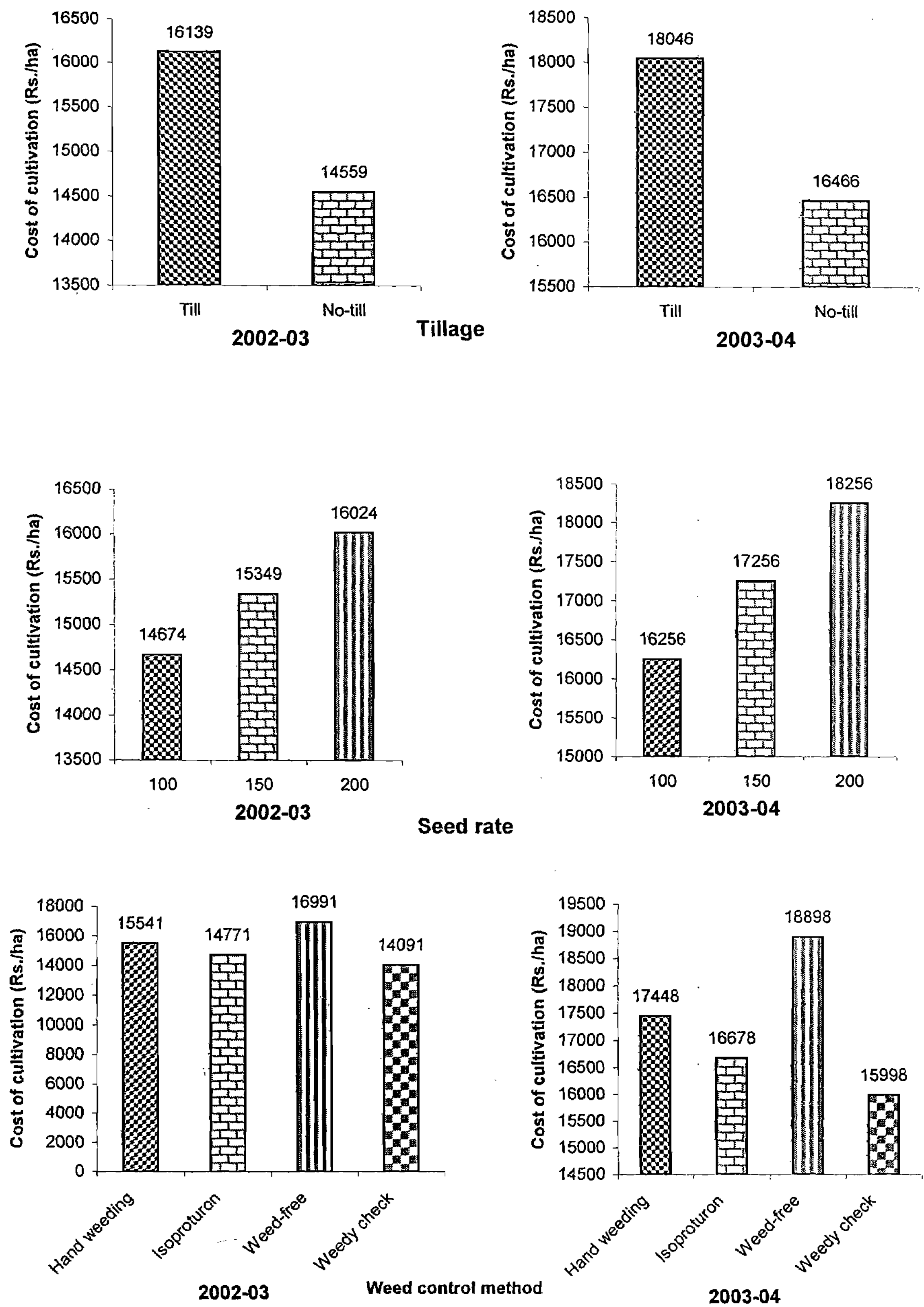


Fig.10: Cost of cultivation (Rs. ha^{-1})as influenced by tillage, seed rate and weed control method during both the years

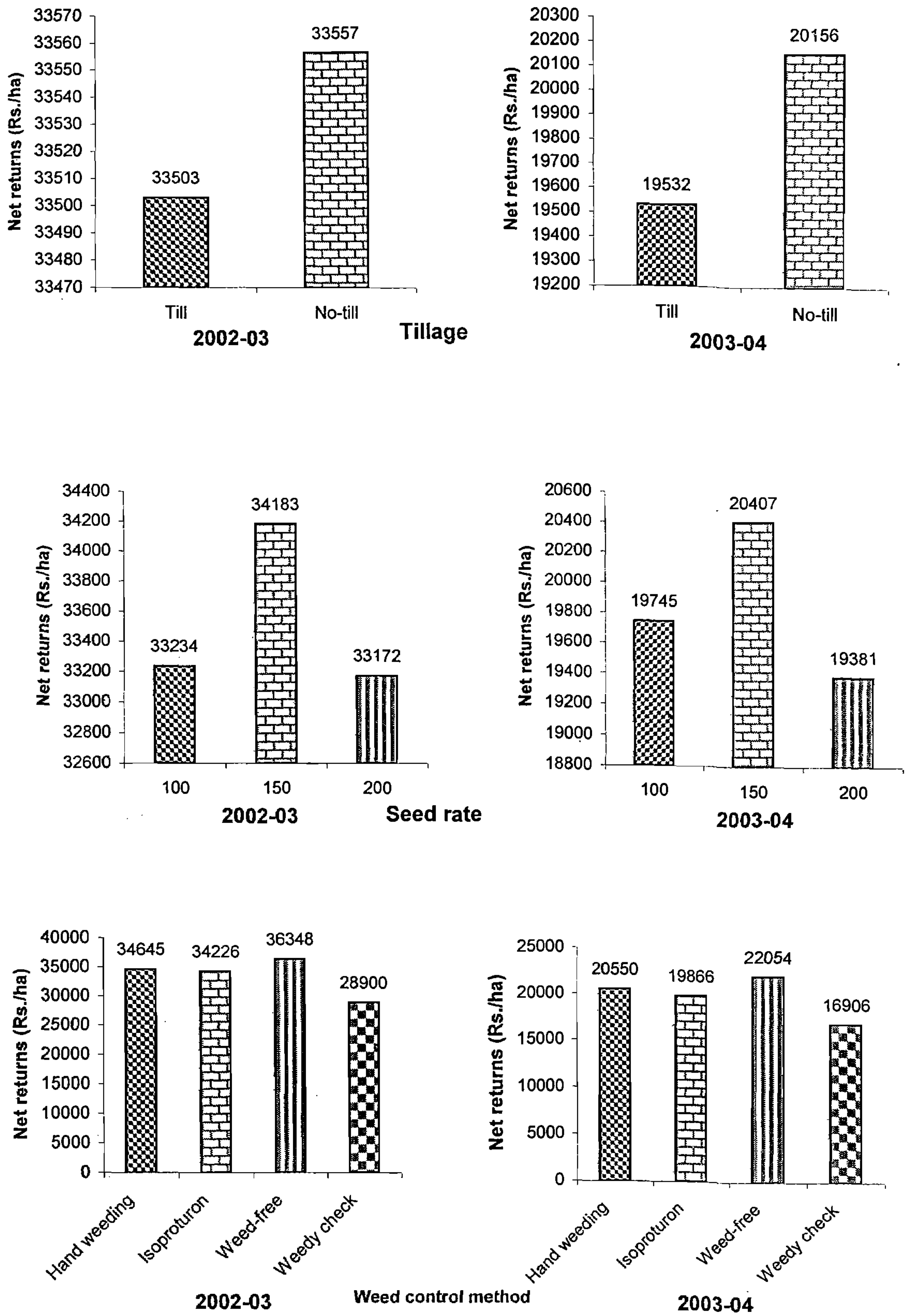


Fig.11: Net returns (Rs. ha^{-1}) as influenced by tillage, seed rate and weed control method during both the years

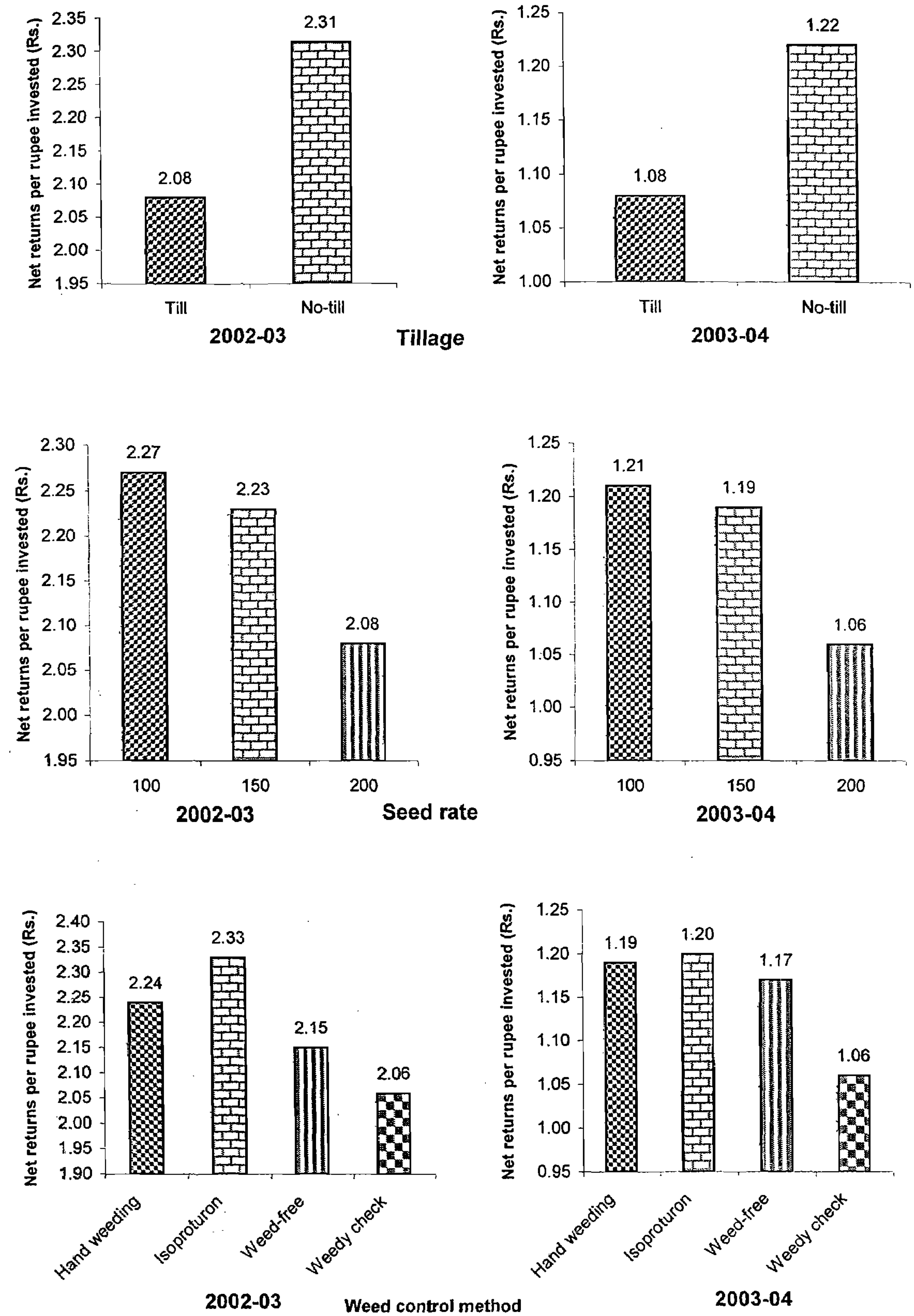


Fig.12: Net returns per rupee invested (Rs.) as influenced by tillage, seed rate and weed control method during both the years

DISCUSSION

5. DISCUSSION

Here an attempt is made to discuss the results presented in the preceding chapter to explain and understand 'cause and effect' relationship of various treatments with reasons wherever possible for getting information of practical utility.

Yield of a crop is the result of growth and development of individual plant, depending upon its genetic potential and the environment to which it is exposed during the course of its life cycle.

5.1 Effect of tillage

Differences in grain yield due to tillage were not statistically significant during both the years (Table 15), but grain yield recorded under till was 5.74 and 5.45 per cent higher over no-till treatment during 2002-03 and 2003-04, respectively. This increase in grain yield might be as result of non-significant increase noted in biological yield, plant dry weight, leaf area index, number of spikes and less crop-weed competition. Willium (2001) also reported non-significant differences in grain yield due to tillage practices. Das and Verma (2003) also reported higher grain yield due to conventional tillage.

Non-significant but higher straw yield noted under till treatment might be due to non-significantly higher number of shoots, dry matter accumulation and leaf area index (Table 15). Higher straw yield with till treatment was noted by Das and Verma (2003). Chauhan *et al.* (2003) also noted non-significant differences in straw yield due to tillage.

On contrary spike length, fertile spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1} and 1000-grain weight were slightly higher under no-till treatment (Table 13 and 14). Pandey *et al.* (2001) and Singh (2001) also reported that tillage practices did not affect the spike length, fertile spikelets spike^{-1}, number of grains spike^{-1} and 1000-grain weight significantly. But Singh (2001) and Srivastava *et al.* (2002) reported no-tillage practice was superior as regards to spike length, spikelets spike^{-1} and 1000-grain weight.

Significantly higher plant stand at 20 DAS, number of shoots at different stages and number of spikes per unit area recorded under till treatment (Table 3, 4 and 12) might be due to better field preparation which resulted better germination initially and less crop weed competition at later stages, which resulted more number of shoots per unit area. However, under no-till treatment lower number of shoot count resulted lower number of spikes. Lower number of shoots with no-till treatment may be due to poor conditions which resulted poor germination and more crop-weed competition consequently lower number of spikes. Srivastava *et al.* (2002) were also of the similar opinion. Dixit *et al.* (2003) also noted poor germination and low plant population with no-tillage.

More plant height recorded with no-till treatment (Table 5) might be due to more crop weed competition which resulted poor interception of light and upward plant growth. Pandey *et al.* (2000) noted non-significant differences in plant height due to tillage treatment. Das and Verma (2003) also noted maximum plant height with no-tillage.

More leaf area index and plant dry weight observed under till treatment (Table 6 and 7) might be due to more number of shoots and less crop-weed competition which resulted better light penetration into lower leaves and simultaneously increased photosynthetic area, more photosynthates and more plant dry weight. Singh (2001) also observed significantly more leaf area under conventional tillage. Das and Verma (2003) reported significantly higher dry matter production under conventional tillage.

Higher root length density and dry weight recorded under conventional tillage practice (Table 10) was due to favourable environment for plant growth i.e. reduced bulk density of soil, optimum air and moisture pool and increased availability of nutrients to plants. Hajabbasi (2001) and Aggarwal and Sharma (2002) were also of similar opinion.

Significantly lower weed density noted under no-till treatment at initial stages, but at later stages, lower with till treatment (Table 17) may be due to that at early stage tillage provided favourable environment for better germination of weed seeds due to better contact, but under no-till condition weed seeds remained at soil surface. At later stage and maturity lower weed density with till treatment may be due to infestation of annual weeds as they complete their life cycle normally within 70-85 days, but under no-till condition there was more infestation due to perennial weeds.

Significantly less dry weight was recorded with till treatment at 30, 90 and 120 DAS, but at 60 DAS it was less with no-till treatment (Table 18). Under no-till, weed dry weight increased with increasing crop duration may be due to more infestation of perennial weeds, but under till treatment, maximum growth of weeds at 60 days stage was due to annual nature of growth but at maturity annual weeds completed their life cycle. Skorda *et al.* (1997) recorded less annual, but more grassy and perennial weeds with no-till. Workayehu and Workayehu (2000) reported that weed density was 79 per cent higher under no-tillage at maturity. Tueseca *et al.* (2001) concluded that annual broad-leaved weeds showed higher population in conventional tillage as grassy annual and perennial species and an erratic response to tillage system. Similarly Das and Verma (2003) stated that weed density and dry weight was lower under conventional tillage.

Weed control efficiency noted higher under till treatment was due to suppression of weeds by dense crop canopy (Table 19). Crop-weed competition was significantly lower under till treatment (Table 20) which might be due to higher number of shoots and leaf area index which lead to lower crop-weed competition.

Significantly higher nitrogen and phosphorus content in grain and straw, both recorded under no-till treatment (Table 21 and 22) might be due to higher organic matter content and there slowly decomposition provide the nutrient to the crop throughout the seasons. But tillage system did not significantly influenced potassium content in grain and straw (Table 23), however slightly higher potassium content recorded with till treatment may be due to most of the potassium fixed in the lower layer under no-till which was unavailable to the plant. Mozafar *et al.* (2000) reported that the concentration of phosphorus and potassium was higher in the plants under no-tillage. However, Ishaq *et al.* (2003) reported that concentration of nitrogen, phosphorus and potassium in plants and grain was not affected significantly.

Data on nutrient uptake in both the crop seasons indicate that the tillage system did not significantly influenced nitrogen, phosphorus and potassium uptake (Table 24). However, higher nitrogen uptake recorded with no-tillage may be due to more nitrogen content under no-tillage treatment. While, potassium uptake found higher under till condition may be due to more potassium content and grain and straw yield with till condition. Aggarwal and Sharma (2002) noted that nitrogen-uptake by wheat was not influenced by tillage practices.

Lower removal of nitrogen, phosphorus and potassium by weeds recorded under no-till treatment at 60 DAS (Table 25), might be because of lower weed dry weight with no-till at 60 DAS.

Higher cost of cultivation recorded under till treatment was due to extra expenditure on energy for field preparation which resulted higher cost of cultivation (Kosutic *et al.*, 2001; Dixit *et al.*, 2003 and Pandey *et al.*, 2003).

Higher gross return obtained under till treatment (Table 26) was due to higher grain and straw yield under this treatment. Significantly higher net return per rupee invested obtained under no-till treatment was due to less cost of cultivation with this treatment. However, Chauhan *et al.* (2003) and Pandey *et al.* (2003) found that no-till treatment was more profitable because of 28 per cent reduction in the average cost of production with no-tillage.

5.2 Effect of seed rate

Data on grain yield in both the crop seasons indicate that seed rate did not influenced grain yield significantly (Table 15), however grain yield from 100 to 150 kg increased but 200 kg seed rate did not add extra yield. Increase in grain yield due to 150 and 200 kg seed rate over 100 kg was 4.18 and 3.21 per cent during 2002-03 and 5.37 and 6.42 per cent during 2003-04. Even though the higher seed rate of 150 and 200 kg helped in increasing the number of shoots m^{-2} at all the growth stages and ultimately number of spikes m^{-2} resulted slightly higher grain yield but not significantly increased with higher seed rate might be due to increased crop competition among plants for light, nutrient, water, CO_2 and space with increasing seed rate. Jena and Behra (1998), Shaukat *et al.* (1999) and Bairwa *et al.* (2000) found that grain yield increased upto 150 kg seed rate.

Significantly higher number of spikes (Table 12) was recorded with higher seed rate (150 and 200 kg ha^{-1}) but significant increase in spike number was not observed beyond 150 kg seed rate may be due to increased competition among plants. Singh *et al.* (2002) and Sen *et al.* (2003) were also of similar opinion.

In both the seasons spike length was found maximum with 100 kg seed rate (Table 13). Similar results were put forth by Singh *et al.* (1999). Fertile spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1} as well as 1000-grain weight were recorded highest with 100 kg seed rate in both the seasons but differences were not significant (Table 13 and 14). With 100 kg seed rate probably there was more availability of light, nutrients, moisture, CO_2, and space which resulted efficient diversion of nutrients towards the sink. But at higher seed rates more plant population resulted limited nutrient supply. More number of ineffective tillers resulted less photosynthates available for translocation towards grain as a result fertile spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1} and 1000-grain weight decreased with increasing seed rate. Pandey *et al.* (1999) reported that number of fertile spikelets spike^{-1} decreased with increasing seed rates. Singh *et al.* (2002) reported that number of grains spike^{-1} decreased with increasing seed rate. Singh and Uttam (1993) noted significant decrease in grain weight spike^{-1} at higher seed rate. Biswas *et al.* (1999) reported highest 1000-grain weight at lower seed rate and it decreased with increase in seed rate. Similar results were put forth by Wood *et al.* (2003).

In both the crop seasons increasing seed rate did not have a significant influence on straw yield (Table 15). This may be attributed to higher number of shoots per unit area obtained with 150 and 200 kg seed rate at initial stages of crop growth. Later shoot drying after flowering stage owing to increased temperature as a result all the shoots did not contribute as ear bearing tillers.

Therefore, at maturity, there was no significant effect on dry matter production with increasing seed rate and also it did not have a significant influence on straw yield. Similar findings were reported by Azimzadeh and Koocheki (1999) and Bairwa *et al.* (2000).

Significantly higher reproductive period recorded with 100 kg seed rate (Table 11) may be due to less competition among crop plants resulting late maturity.

Significant increase in dry matter production from 100 to 200 kg seed rate at initial stages may be due to higher seed rate which resulted higher plant population at initial stage of crop growth and higher dry matter production but at later stage, these might be higher shoot mortality due to over crowding with higher seed rate. Similar results were reported by Wood *et al.* (2003).

Significantly higher leaf area index (LAI) recorded with 200 kg seed rate at all the stages of crop growth except 120 days stage (Table 6) might be due to increasing seed rate also increased plant population significantly and resulted increase in leaf area per unit area but it decreased plant^{-1}. At 120 days LAI did not increase with higher seed rate due to higher competition. Due to high plant population the extent of light penetration into plant canopy reduced and resulted early leaf senescence at 200 kg seed rate. Similarly, Singh *et al.* (2003) reported highest LAI at 150 kg seed rate. Singh *et al.* (2002) also reported decreased number of leaves plant^{-1} with increasing seed rates.

At 90 and 120 days stages significantly taller plant observed with 100 kg seed rate (Table 5) might be due to more availability of nutrients, moisture, and light with 100 kg seed rate because of less competition. Singh *et al.* (2002) obtained taller plants with 100 kg seed. While Arif *et al.* (2002) reported maximum plant height with maximum seed rate.

Reduction in weed dry weight and weed density recorded with increasing seed rate upto 200 kg (Table 17 and 18) might be due to more competitiveness of crop with weeds. Roslon and Fogel Fors (2003) also reported decrease in weed density and weed dry weight with increase in seed rate. Higher weed control efficiency noted with higher seed rate (200 kg) might be due to (Table 19) more suppression of weeds by crop canopy. Significantly lower crop weed competition index recorded with higher seed rate (Table 20a) might be due to better suppression of weeds by crop canopy (Korres and Froud Williams, 2002).

Decrease in nitrogen, phosphorus and potassium content in the grain and straw with increasing seed rate and significantly higher phosphorus content in grain and straw at 100 kg seed rate (Table 21, 22 and 23) might be due to the increased competition among the plants. Similar results were obtained by Gooding *et al.* (2002).

Higher uptake of nitrogen, phosphorus and potassium by wheat crop was recorded with 100-150 kg seed rate and slightly lower phosphorus uptake with higher seed rate (Table 24). Significantly lower removal of nitrogen, phosphorus and potassium by weeds recorded under higher seed rate (Table 25) might be due to better weed control with higher seed rate. Kaur *et al.* (2002) reported that higher seed rate decreased nitrogen, phosphorus and potassium removal by weeds.

Higher cost of cultivation recorded with higher seed rate and its increase with increased seed rate upto 200 kg might be because of more quantity of seed used for sowing. Similarly higher gross return recorded with higher seed rate (Table 26) might be due to more grain and straw yield obtained with higher seed rate.

Higher net return was obtained with 150 kg seed rate but net return per rupee invested was obtained significantly higher with 100 and 150 kg seed rates (Table 26) because of lower cost of cultivation with 100 and 150 kg seed rate as compared to 200 kg. Pandey *et al.* (1999) and Bairwa *et al.* (2000) reported that net return and net return $rupee^{-1}$ invested increased significantly upto 150 kg seed rate and further increase in seed rate failed to show significant effect.

5.3 Effect of weed control method

Significantly higher grain yield was recorded under weed free followed by hand weeding and isoproturon treatments. Increase in grain yield due to weed free, hand weeding and isoproturon treatments over control was 36.00, 25.85 and 21.16 per cent during 2002-03 and 37.51, 26.91 and 20.44 per cent during 2003-04, respectively (Table 15). This increase in grain yield may be attributed to significant increase in number of spikes per unit area, spike length, fertile spikelets, number of grains spike^{-1}, grain weight spike^{-1} and 1000-grain weight under treated plots. Besides, cumulative effect of reduced crop-weed competition, better growth and development of crop plants also contributed to higher grain yield. Jain*et al.* (1998) also observed that use of isoproturon gave significantly higher grain yield than unweeded control. Chopra *et al.* (2001) recorded maximum grain yield in weed free followed by isoproturon at 0.75 and 0.50 kg ai ha^{-1} treatment. Singh and Saha (2001) noted that two hand weeding treatment was better option to obtain higher yield. Pandey and Verma (2002) and Punia *et al.* (2003) reported maximum increase in grain yield under weed free and proved significantly superior over isoproturon @ 1.0 kg ai ha^{-1}.

Significantly higher number of spikes recorded with weed free, hand weeding and isoproturon treatments (Table 12) indicated better growth, environment and less competition among plants. Singh and Saha (2001) and Pandey and Verma (2002) observed that number of productive tillers was significantly higher under hand weeding followed by isoproturon @ 1.0 kg ai ha^{-1}. Similarly Pandey and Prakash (2003) observed that number of spikes m^{-2} increased with increasing duration of weed free condition and it decreased with increasing weedy condition.

Maximum spike length, fertile spikelets, number of grains spike^{-1}, grain weight spike^{-1} and 1000-grain weight were recorded under weed-free treatment followed by hand-weeding and isoproturon (Table 13 and 14). This increase was obviously the result of better weed control which rendered favourable conditions (nutrient uptake, moisture availability and sunlight to the crop plants).These results are in conformity with Pandey and Verma (2002), Punia *et al.* (2003) and Pandey and Prakash (2003).

Highest straw yield noted under weed-free treatment followed by hand-weeding and isoproturon (Table 15) might be attributed due to increased plant height, number of shoots, number of leaves, leaf area index and dry matter accumulation under these treatments. Pal (2002) observed that uncontrolled weeds reduced straw yield by 38 per cent compared with weed free condition. Significantly higher straw yield was observed under weed free followed by isoproturon @ 1.0 kg ai ha^{-1}. Similar findings were reported by Das and Verma (2003).

Significantly higher number of shoots and plant dry weight were recorded with weed free treatment followed by hand-weeding and isoproturon (Table 4 and 7) which might be due to more removal of weeds from treated plots. These findings are conformity with Pal (2002). Das and Verma (2003) and Aggarwal *et al.* (2003) also reported that crop dry weight was higher under isoproturon treated plots than the weedy.

Under weed free plots weed population and weed dry weight noted zero was due to the weed free condition maintained throughout the crop season. Significantly lower weed density and weed dry weight recorded under hand weeding followed by isoproturon (Table 17 and 18) might be due to better removal of weeds from treated plots. Singh *et al.* (2000) concluded that lowest weed density and dry weight was recorded under hand weeding at 30 days after sowing followed by isoproturon at 1.0 kg ai ha^{-1}. Pandey and Verma (2002) also reported that weed control decreased weed population and weed dry weight significantly. Weed density and dry weight under hand weeding was significantly lower than isoproturon @ 1.0 kg ai ha^{-1} and weedy check. Punia *et al.* (2003) also reported that application of isoproturon @ 1.0 kg ai ha^{-1} applied 35 days after sowing gave 62.5 per cent control of grassy weeds. Significantly higher weed control efficiency and lower crop weed competition index were recorded with weed free treatment followed by hand weeding and isoproturon (Table 19 and 20a) which might be due to better weed control (Singh *et al.* 2003 and Pandey and Prakash, 2003).

Plant height did not differ significantly due to different weed control methods from 30 to 90 days, but at 120 days stage significantly higher plant height was recorded with weed free followed by hand weeding and isoproturon treatments (Table 5) which might be due to better supply of nutrients and favourable environment to which crop was exposed. Similar findings were put forth by Pandey and Verma (2002), and Das and Verma (2003).

Significantly more leaf area index was noted under weed free followed by hand weeding and isoproturon treatments (Table 6) which might be due to more plant height, leaf number, number of shoots and better weed control as reported by Pal (2002).

Significantly longer maturity and reproductive period were recorded under weed free followed by hand weeding and isoproturon treatments (Table

11) which might be due to more competition among whole vegetation (crop + weed) with weedy for nutrient, moisture, light and space.

Significantly more nutrient content in grain and straw and uptake of nitrogen, phosphorus and potassium by the crops noted under weed free treatment followed by hand weeding and isoproturon (Table 21, 22, 23 and 24) might be due to better control of weeds in treated plots which resulted better availability of nutrients to the crop during growth period and similarly higher grain and straw yield noted in treated plots turned into higher uptake by the crop. These results are in close agreement with those reported by Singh and Saha (2001).

Significantly lower removal of nitrogen, phosphorus and potassium by weeds recorded under hand weeding followed by isoproturon might be due to suppression of weed growth brought about by these treatments (Table 25). These findings are conformity with Pal (2002).

Significantly higher gross return and net return recorded under weed-free followed by hand weeding and isoproturon might be because of significantly more grain and straw yield with treated plots. Similarly, significantly more net return per rupee invested was noted with isoproturon treatment followed by hand weeding and weed free treatment (Table 26) because of low cost was involved in chemical weed control. Under weed free treatment more cost involved in weed removal but due to more yield it resulted more net return per rupee invested than weedy check. Das and Verma (2003) reported that isoproturon @ 1.0 kg ai ha^{-1}, 30 days after sowing was found more remunerative weed control method which gave higher gross return, net return and net return per rupee invested.

Yield gap noted between two years was mainly due to variation in climate and varieties used. Besides distinct variation in amount and distribution of rainfall fluctuations and magnitude of temperature, solar radiation and wind speed also caused variation in growth and productivity of crop and growth of weeds as during 2002-03 there was more and well distributed rainfall, more variation in maximum and minimum temperature, solar radiation, wind velocity and pan evaporation.

UP-2382 variety has vigorous growth and longer reproductive period and produced more yield during 2002-03. While variety UP-2425 used in second year (2003-04) was of short duration and yielded comparatively lesser than previous year. In addition to yield, yield attributes, growth attributes and weed growth, uptake by the crop and removal of nutrients by the weeds also affected accordingly.

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

A field experiment was conducted during 2002-03 and 2003-04 at Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar to study the effect of seed rate and weed control method on growth and productivity of wheat under till and no-till condition. Treatments comprised of two tillage practices (i.e. till and no-till), three seed rates (i.e. 100, 150 and 200 kg ha^{-1}) and 4 weed control methods (i.e. hand weeding at 30 DAS, isoproturon @ 1.0 kg a.i. ha^{-1} at 35 DAS, weed free and weedy check). All the twenty four treatment combinations were replicated thrice in a split-plot design, keeping tillage and seed rate as main-plot and weed control method as sub-plot. Salient findings of the present study are summarized as below:

6.1 Effect of tillage

During both the years, number of spikes, plants (20 DAS) and number of shoots at all the stages noted under till treatment were significantly higher. Similarly plant dry weight (30 DAS), LAI (30 and 60 DAS in 2002-03), weed control efficiency (60 and 90 DAS) and gross return (2003-04) were also significantly higher under till treatment. But weed density (120 DAS), weed dry weight (30, 90 and 120 DAS) and crop weed competition index recorded with till treatment was significantly lower.

Higher grain yield, biological yield grain straw ratio, LAI, plant dry weight at all the stages, $\overline{CGR}$ (30-60 and 60-90 days interval), root length density, root dry weight at all the soil depths, weed control efficiency (120 DAS), potassium content in grain as well as in straw, cost of cultivation and gross return were recorded under till treatment during both the years.

Significantly more number of fertile spikelets spike^{-1} (2003-04) plant height (120 DAS, 2003-04), days to maturity and reproductive period, nitrogen and potassium content in grain as well as in straw and net return rupee^{-1} invested were noted with no-till treatment during both the years. Whereas, weed density (60 DAS) and weed dry weight were significantly lower under no-till treatment.

Higher, straw yield, spike length, fertile spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1}, 1000-grain weight, $\overline{CGR}$ (90-120 days intervals), $\overline{RGR}$ at all the stages, nitrogen uptake and net return were noted with no-till treatment during both the years. However, weed density (30, 60 and 90 DAS), nitrogen, phosphorus and potassium removal by weeds (60 DAS) was observed lower with no-till treatment during both the years.

6.2 Effect of seed rate

Significantly more spike length (2002-03), days taken to heading (2002-03), maturity and reproductive period, plant height (120 DAS, 2003-04), phosphorus content in grain and straw, nitrogen content in straw (2003-04), and net return rupee^{-1} invested were recorded with 100 kg seed rate during both the years. While significantly lower removal of nitrogen, phosphorus and potassium by weeds were also observed with 100 kg seed rate.

More spike length, fertile spikelets, number of grains spike^{-1}, grain weight spike^{-1}, 1000-grain weight, days taken to heading, RGR, nitrogen content in grain and straw, nitrogen uptake, potassium content in grain and straw, potassium uptake were also recorded with 100 kg seed rate. Significantly more number of spikes was recorded with 150 kg seed rate during 2002-03.

Higher biological yield, grain yield (2002-03), straw yield (2002-03), grain-straw ratio (2002-03), LAI (120 DAS, 2002-03), $\overline{\text{CGR}}$ (60-90 and 90-120 days interval), phosphorus uptake, potassium uptake (2003-04), gross return and net return were observed at 150 kg seed rate.

Significantly more number of spikes, plant stand (20 DAS), number of shoots at all the growth stages, LAI (30, 60 DAS, 2002-03 and 30, 60, 90 DAS, 2003-04), plant dry weight (30 and 60 DAS) and gross return (2003-04) were noted with 200 kg seed rate. While, weed density (90 DAS, 2002-03 and 120 DAS, 2003-04), weed dry weight at all the stages and crop weed competition index were also significantly lower with 200 kg seed rate.

Higher straw yield (2003-04), grain yield (2003-04), grain-straw ratio (2003-04), sterile spikelets spike^{-1}, plant height at all the stages except 120 DAS (2003-04), plant dry weight (90 and 120 DAS), $\overline{\text{CGR}}$ (30-60 days intervals), weed control efficiency at all the stages and cost of cultivation were noted under 200 kg seed rate. But weed density was found lowest with 200 kg seed rate.

6.3 Effect of weed control method

Grain yield, biological yield, straw yield (2003-04), grain straw ratio, grain weight spike^{-1} (2003-04), days taken to heading and maturity, reproductive period, number of shoots, leaf area index, plant dry weight at 60, 90 and 120 days stages, plant height at maturity, $\overline{\text{CGR}}$ at 30-60 and 60-90 days period and $\overline{\text{RGR}}$ at 30-60 days period recorded under weed free treatment were significantly higher over all other treatments. Further hand weeding was closely followed by isoproturon treatment.

Spike length, fertile spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1} (2002-03) and 1000-grain weight recorded under weed free treatment were maximum.

Significantly lowest weed density, weed dry weight, crop-weed competition index but highest weed control efficiency were recorded under hand weeding which was closely followed by isoproturon during both the years. But weed free treatment was found superior over all the weed control treatments during both the years.

Significantly higher content of nitrogen, phosphorus and potassium in grain and straw, more uptake of nitrogen, phosphorus and potassium were recorded under weed free treatment, followed by hand weeding and isoproturon treatments. While, nitrogen, phosphorus and potassium removal by weeds was also noted significantly lower under hand weeding treatment and it was followed by isoproturon during both the years. Weed free treatment was found superior over all the weed control treatments with regard to weed density, weed dry weight, weed control efficiency, crop weed competition, nutrient uptake by the crop, nutrient removal by the weeds during both the years.

Higher cost of cultivation was recorded with weed-free > hand weeding> isoproturon treatments in order and was minimum with weedy check during both the years.

Significantly higher gross and net return was recorded under weed free treatment followed by hand weeding and isoproturon treatment during both the years. While significantly higher net return $rupee^{-1}$ invested was obtained under isoproturon treatment followed by hand weeding and weed-free treatments during both the years.

CONCLUSION

On the basis of this investigation it is concluded that though maximum grain yield was obtained with weed free followed by hand weeding at 150 kg ha^{-1} seed rate under till (conventional) but no-till at 200 kg ha^{-1} seed rate also produced comparable grain yield. Isoproturon at 1.0 kg ai ha^{-1} and seed rate at 100-150 kg ha^{-1} under no-till treatment was found economically better. However, it needs further experimentation.

LITERATURE CITED

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Aggarwal, Navneet; Mehra, S.P.; Bhatia, R.K. and Singh, Surjit. 2003. Efficacy of Trifluralin against *Phalaris minor* and Broad leaf weeds in wheat (*Triticum aestivum* L.). *Indian J. Weed Sci.* 35(3&4): 253-254.

Aggarwal, P. and Sharma, N.K. 2002. Water uptake and yield of rainfed wheat in relation to tillage and mulch. *Indian J. of Soil Conservation.* 30(2): 155-160.

Ahuja, K.N.; Lal, R.B.; Kumar, A. and Kumar, A. 1996. Effect of seed rate, date and method of sowing on growth and yield of wheat. *Annals of Agricultural Research.* 17(2): 190-192.

Andersson, B. 1988. Seed rates in spring cereals with and without weed control. Weeds and weed control. 29th Swedish Weed Conference. Uppsala 27-28 January, Vol. 1: 1-10.

Arif, M.; Taj, F.H.; Kakar, K.M. and Nawab, K. 2002. Seed rates effect on wheat varieties. *Sarhad J. of Agriculture (Pakistan).* 18(3): 259-261.

Arshad, M.A.; Gill, K.S. and Roy, G.R. 1994. Wheat yield and weed population as influenced by three tillage systems on a clay soil in temperate continental climate. *Soil and Tillage Research.* 28(3-4): 227-238.

Asefa, T.; Tanner, D.G.; Shambel, M.; Taa, A.; Girma, K.; Gorfu, A. and Maru, S. 2000. Effect of tillage and cropping sequence practices on wheat production. The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa, Addis Ababa, Ethiopia, 18-22 Sept. 2000. 275-290.

Azad, B.S. and Singh, H. 1997. Effect of weed-control measures and nitrogen on productivity of wheat (*Triticum aestivum*). *Indian J. of Agronomy.* 42(1): 98-103.

Azad, B.S.; Bhagat, B.D.; Bali, S.V.; Kachroo, D. and Gupta, S.C. 1998. Response of late-sown wheat (*Triticum aestivum*) to seed rate and fertilizer level. *Indian J. Agron.* 43(4): 653-656.

Azad, B.S.; Singh, H.; Gupta, S.C. and Singh, H. 1997. Effect of plant density, dose of herbicides and time of nitrogen application on weed suppression and its efficiency in wheat (*T. aestivum*). *Environment and Ecology,* 15(3): 665-668.

Azimzadeh, M. and Koocheki, A. 1999. Effect of different seeding rates and amount of phosphorus fertilizer on yield and yield components of dryland wheat in northern Khorsan. *Agricultural Sci. and Tech.* 13(2): 131-139.

Bainade, S.S. and Patel, Z.G. 1991. Nutrient losses through weeds in irrigated wheat as influenced by weed control methods and nitrogen level. *Indian J. Agron.* 36: 67-71.

Bairwa, O.P.; Dadheech, R.C. and Sumeriya, H.K. 2000. Effect of seed rate, methods of sowing and varieties on yield, N, P and K uptake and economics in wheat (*T. aestivum* L.). *Annals of Biology, Ludhiana,* 16(1): 75-78.

Bellido, L.; Rafael, J. Lopez-Bellido, Juan E. Castillo and Francisco, J. Lopez-Bellido. 2000. Effects of tillage, crop rotation and nitrogen fertilization on wheat under rainfed mediterranean conditions. *Agron. J.* 92:1054-1063.

Biswas, P.; Kamal, A.M.A.; Rahman, M.M. and Samanta, S.C. 1999. Effect of seed rate, split application of nitrogen and time of irrigation on growth, yield and protein content of wheat. *Bangladesh J. of Scientific and Industrial Research.* 34(2): 312-314.

Brar, S.S.; Walia, S.S.; Singh, J. and Singh, J. 1995. Efficacy of isoproturon for control of *Phalaris minor* in wheat as influenced by residue management system under rice-wheat sequence. *Indian J. Ecology.* 22(1): 11-16.

Chahal, P.S.; Brar, H.S. and Walia, U.S. 2003. Management of *Phalaris minor* in wheat through integrated approach. *Indian J. Weed Sci.* 35(1&2): 1-5.

Chauhan, D.S. ; Sharma, R.K.; and Chhokar, R.S. 2003. Comparative performance of tillage options in wheat (*Triticum aestivum*) productivity and weed management. *Indian Journal of Agricultural Sciences*, 73(7): 402-6.

Chauhan, D.S.; Sharma, R.K.; Verma, U.S.; Nagarajan, S. (ed.). Singh, G. (ed.) and Tyagi, B.S. 1998. Integrated weed management in wheat through tillage options and new molecules under rice-wheat system. Wheat Research Weeds Beyond 2000. A.D. In Proc. Conf. 12-14 August 1997, Karnal, India, 263-273.

Chopra, Nisha; Singh, Harpal; Tripathi, H.P. and Chopra, N.K. 2001. Performance of metsulfuron methyl and pendimethalin alone and their mixtures with isoproturon on weed control in wheat (*Triticum aestivum*) seed crop. *Indian Journal of Agronomy,* 46(4): 682-688.

Christensen, S. 1994. The effect of seed rate and drilling rate of winter wheat on herbicide efficacy. S.P. Report presented at the 11th Danish Plant protection conference on the side effect of pesticides used on weeds. No. 6: 105-114.

Christensen, S. and Rasmussen, G. 1996. Crop weed competition and choice of variety, seed rate and drilling date in winter wheat. *13th Danish Plant protection conference : side effects of pesticides, weeds.* SP Rapport-Statens Planteavlsforsog. No. 3: 103-111.

Clements, D.R.; Weipe, S.F.; Brown, R.; Stonhouse, D.P.; Hume, D.I. and Swanton, C.J. 1995. Energy analysis of tillage and herbicides inputs in alternative weed management systems. *Agric. Eco. Syst. Environ.* 52(2-3): 119-128.

Cochran, W.G. and Cox, G.M. 1959. Experimental designs. *Asia Publishing House, New Delhi.*

Cornish, P.S. and Lymbery, J.R. 1987. Reduced early growth of direct drilled wheat in Southern New South Wastes. Causes and consequences. *Australian J. Expt. Agril.* 27(6): 869-880.

Das, K. 1996. Effect of time of sowing and seed rate on yield of wheat under later sown rainfed conditions in Assam. *J. of the Agricultural Sci. Soc. of North-East India.* 9(1):96-97.

Das , R. and Varma, S.C. 2003. Management of weeds, nitrogen and tillage operations in wheat (*Triticum aestivum*) sown after puddled rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences*, 73(5): 286-88.

David J. Bonfil; Mufradi, I.; Klitman, S. and Asido, S. 1999. Wheat grain yield and soil profile water distribution in a No-till arid environment. *Agron. J.*, 91: 368-373.

Dhawan, R.S. 1995. Effect of isoproturon on hill activity and membrane permeability in leaves of wheat, *Phalaris minor* and *Avena ludoviciana*. *Indian J. Agricultural Sci.* 65(2): 894-895.

Dixit, A. and Bhan, V.M. 1996-97a. Evaluation of glyphosate in conservation tillage system.

Dixit, A.; Bhan, V.M. and Dixit, A. 1998. Influence of isoproturon application for controlling *Phalaris minor* in wheat. *World Weeds.* 5(1-2): 53-56.

Dixit, Jagvir; Gupta, R.S.R.; Behl, V.P. and Yadav, Roshan Lal. 2003. No-tillage and conventional tillage system evaluation for production of wheat-an analysis. *Indian J. Agric. Res.*, 37(3): 199-203.

Gaffer, M.A.; Khan, E.A.; Alam, M.S. and Adhikary, S.K. 1997. Influence of planting density and time of weeding on weed infestation and yield performance in wheat. *Bangladesh J. of Scientific and Industrial Research.* 32(1): 30-34.

Gautam, R.C. 2001. Wheat production assured success in battle against hunger and poverty. *Indian Farming.* 51(7): 23-28.

Gill, K.S. and Aulakh, B.S. 1984. Wheat yield and soil bulk density response to some tillage systems on an Oxisol. *Soil Till. Res.* 18: 37-45.

Gooding, M.J.; Pinyosinwat, A. and Ellish, R.H. 2002. Responses of wheat grain yield and quality to seed rate. *J. of Agricultural Sci.* 138(1): 317-331.

Greenwood, S.J.; Verstraeten, I.M.J. and Draycott, A. 1987. Response of winter wheat to N-fertilizer : quantitative relations for components of growth. *Fertilizer Research.* 12(2): 119-137.

Hajabbasi, M.A. 2001. Tillage effects on soil compactness and wheat root morphology. *J. of Agricultural Sci. and Tech.* 3(1): 67-77.

Halvorson, A.D.; Black, A.L.; Krupinsky, J.M. and Merrill, S.D. 1999. Dryland winter wheat response to tillage and nitrogen with in an annual cropping system. *Agron. J.* 91: 702-707.

Hassan, S.W.; Khan, S.; Khan, M.A. and Khan, S.R. 1994. Effect of different level of herbicides on weed population and grain yield of wheat. *Sarhad J. Agril.* 10(2): 117-120.

Ishaq, M.; Ibrahim, M. and Lal, R. 2003. Tillage and fertilizer effects on root growth of wheat and cotton on a sandy clay loam soil in Pakistan. *J. of Sustainable Agric.* 22(3): 43-57.

Jackson, M.L. 1973. Soil chemical analysis, Prentice Hall Pvt. Ltd. New Delhi, 498 p.

Jaggi, A.; Yadav, S.K. and Jaggi, A. 2000. Nutrient saving in wheat through herbicides. *Crop Res. Hissar.* 20(1): 154-157.

Jain, M.P.; Lidder, R.S. and Jain, K.K. 1998. Weed management in wheat (*Triticum aestivum* L.). *World Weeds.* 5(1-2): 125-130.

Jat, R.S.; Nepalia, V. and Chaudhary, P.D. 2003. Influence of herbicides and methods of sowing on weed dynamics in wheat. *Indian J. Weed Sci.* 35(1&2): 18-20.

Jena, S.N. and Behra, A.K. 1998. Effect of row spacing, seed rate and fertilizer levels on weeds and yield of wheat (*T. aestivum*). *Indian Agriculturist.* 42(2): 139-142.

Johri, A.K.; Singh, G.; Sharma, D. and Singh, G. 1992. Nutrient uptake by wheat and associated weeds as influenced by management practices. *Tropical Agriculture.* 69(4): 391-393.

Kandop, S. and Upadhyay, U.C. 1995. A practical mannual on weed control. Oxford and IBH. Pub. Co. Pvt. Ltd., New Delhi, pp 43-44.

Karim, S.M.R.; Aziz, M.A.; Shalauddin, A.B.M. and Islam, N. 1998. Effects of seed rate and relative time of seeding on the performance of relay wheat in transplanted autumn rice. *Thailand J. of Agricultural Sci.* 31(4): 569-576.

Kaspar, J. and Fischbeck, G. 1988. Effects of reduced weed control procedures on the incidence of weeds and development of yield in winter wheat. *Mitteilungen-der-Gessellschaft-fur-Pflanzenbau-wissenschaften.* 1:25-27.

Kaur, R.; Mahal, S.S.; Mahey, R.K.; Kumar, K.; Mathauda, S.S.; Kaur, R. and Kumar, K. 2002. Effect of irrigation and seed rate levels on root mass density, NPK content and uptake on bed planted late sown wheat (*T. aestivum*). *Environment and Ecology.* 20(4): 915-919.

Keeling, W. 1995. Weed and cover crop management in conservation tillage for the south-west. *Proc. Baltwide Cotton Conf.*, San Antonio, Texas, USA, Jan.4-7, 1995, 1: 73-74.

Kim, D.; Kim, S.; Kim, E; Slon, B.Y. and Kang, D.J. 1998. Weed occurrence and control in simultaneous wheat sowing culture with rice harvest under no tilled paddy field. *Korean Journal of Weed Science,* 118(3):186-90.

Korres, N.E. and Froud-Williams, R.J. 1997. The use of varietal selection and seed rates for enhanced weed suppression in winter wheat (*T. aestivum* L.). Brighton crop protection conference : weeds. Proceedings of an international conference, Brighton, UK, 17-20 Nov. 1997, Volume 2, 667-668.

Korres, N.E. and Froud-Williams, R.J. 2002. Effects of winter wheat cultivars and seed rate on the biological characteristics of naturally occurring weed flora. *Weed Research Oxford.* 42(6): 417-428.

Kosutic, S.; Filipovic, D.; Gospodarie, Z.; Kovacov, I. and Copec, K. 2001. Utilization of different soil tillage systems in maize, winter wheat and soybean production. *Aktualni-Zadaci-methanizacije-radova*-29, Veljace. 161-169.

Kumar, R. Jaya and Jagannathan, R. 2003. Book: Weed Science Principles. pp 1-3.

Kumar, R.; Agarwal, S.K.; Nanwal, R.K. and Kumar, R. 2002. Biomass study in bread wheat (*Triticum aestivum* L.) under different planting systems, seed rates and nitrogen levels in sandy loam soils. *Haryana Agricultural Univ. of Research.* 32(2): 73-76.

Kumar, R.; Agarwal, S.K.; Nanwal, R.K. and Kumar, R. 2002. Economics of bread wheat as affected by planting system, seed rate and nitrogen fertilization in sandy loam soils of Haryana. *Haryana Agricultural Univ. J. of Research.* 32(1): 23-25.

Kumar, S.; Singh, G.; Kumar, S. and Singh, G. 1997. Efficacy and selective of tralkoxydim alone or in combination with isoproturon on wheat. *Indian J. Agron.* 42(2): 306-309.

Kumar, S.; Singh, G.; Kumar, S. and Singh, G. 1998. Bioefficacy of isoproturon formulation in wheat and their effect on nutrient uptake. *Annals Plant Protection Sci.* 6(2): 174-177.

Kumpawat, B.S. 1998. Response of late sown wheat (*Triticum aestivum*) to sowing method and seed rate. *Indian J. Agron.* 43(4): 650-652.

Kundra, H.C.; Sidhu, K. and Brar, L.S. 1999. Studies on growth stage susceptibility of (*Phalaris minor* Retz.) to the application of isoproturon in wheat. *The Eight Biennial Conference of the Indian Society of Weed Science*, held during 5-7 February 1999 at Varanasi, Abstr, pp 27.

Kushwaha, B.L.; Singh, K. and Singh, K. 2002. Response of wheat to row spacing, seed rate and fertility level under late-sown condition. *Plant-Archives.* 2(1): 123-126.

Mahajan, G. and Sardana, Virender. 2003. Nutrient uptake by wheat and *Phalaris minor* as influenced by weed management practices. *Agric. Sci. Digest.* 23(3): 195-198.

Malik, R.K. and Singh, S. 1993. Evolving strategies for herbicide use in wheat : resistance and integrated weed management. In: Proc. Int. Symp. on Integrated Weed Management for Sustainable Agriculture, Indian Soc. Weed Sci., Hissar, India, Nov. 18-20, Vol. I: 225-228.

Martin, R.J. and Felton, W.L. 1993. Effect of crop rotation, tillage practice and herbicide on population dynamics of wild oat in wheat. *Australian J. Exp. Agri.* 33(2): 159-165.

Mehta, A.K.; Singh, R. and Hansra, B.S. 2001. Zero tillage sowing of wheat. A boon for farmers. Intensive Agriculture. Jan.-Feb. pp 21-23.

Merrill, S.D.; Black, A.L. and Bauer, A. 1996. Conservation tillage affects root growth of dryland spring wheat under drought. *Soil Sci. Soc. Am. J.* 60: 575-583.

Mishra, S.K. 1996. Effect of seed rate and nitrogen levels on different varieties of wheat sown under zero tillage. M.Sc. Thesis, GBPUA&T, Pantnagar.

Mozafar, A.; Thomas Anken; Richard Ruh and Emmanuel Frossard. 2001. Tillage intensity, mycorrhizal and nonmycorrhizal fungi and Nutrient concentrations in maize, wheat and canola. *Agron. J.* 92:1117-1124.

Nanda, S.S. and Patro, G.K. 1996. Effect of weed management practices, row spacing and fertilizer levels on growth and yield of wheat. *Indian J. Weed Sci.* 28: 67-69.

NATP, 1999-2003. Conservation tillage in rice-wheat cropping system under irrigated agro-ecosystem, final report, Department of Agronomy, NATP Project Pantnagar-263145, India.

Nelson, D.W. and Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. In: Page, A.L.; Miller, R.H. and Keeney, D.r. eds. Method of soil analysis. Part II. American Soc. Agron. Inc. Soil Soc.America, Inc. Madison, Wisconsin, USA. pp 539-577.

Newman, J. 1966. A method of estimating the total length of root in a sample. *J. of Applied Ecology.* 3: 139-145.

Olsen, S.R.; Cole, C.W.; Watnable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with $NaHCO_3$. USDA. Cir. No. 939, Washington, p. 13.

Page, A.L.; Miller, R.H. and Keeney, D.R. 1982. Methods and soil analysis. Part 2 (ed.) No.9 Agron., Series ASA-SSSA Publisher, Madison, Wisconsin, USA.

Pal, D. 2002. Effect of rates of fenoxaprop-p-ethyl alone and in combination with isoproturon on wheat and associated weeds. Thesis, Ph.D. submitted to G.B. Pant Univ. of Agric. & Tech., Pantnagar.

Pandey, A.K.; Prakash, V.; Singh, R.D. and Mani, V.P. 2000. Effect of tillage practices on yield and yield attributes of wheat varieties in rice-wheat cropping system under mid-hills of N-W Himalayas. *Ann. Agric. Res.* 21(4): 548-551.

Pandey, A.K.; Prakesh, Ved. 2003. Studies on weed-crop competition in rainfed wheat under mid-hill conditions of North-west Himalayas. *Indian J. Weed Sci.* 35(1&2): 107-108.

Pandey, A.K.; Singh, P.; Prakash, V.; Singh, R.D.; Chauhan, V.S. and Singh, P. 1999. Direct and residual effect of weed control measures in maize (*Zea mays*) and wheat (*T. aestivum*) cropping system under mid-hill condition of N-W Himalayas. *Indian J. of Weed Science.* 31(3-4): 204-209.

Pandey, H.K. and Rao, J.K.A. 1965. Absorption of nutrients by the crop plant and associated weeds and its relationship with crop yield. *Indian J. Agron.* 10: 306-312.

Pandey, I.B.; Thakur, S.S. and Singh, S.K. 1999. Response of timely sown wheat varieties to seed rate and fertility level. *Indian J. of Agronomy.* 44(4): 745-749.

Pandey, Jitendra and Verma, A.K. 2002. Effect of atrazine, metribuzin, sulfosulfuron and tralkoxydim on weeds and yield of wheat. *Indian Journal of Agronomy,* 47(1): 72-76.

Pandey, L.M.; Suresh pal and Mruthyunjaya. 2003. Impact of zero-tillage technology in the rice (*Oryza sativa*)- wheat (*Triticum aestivum*) system of foothills of Uttaranchal State, India. *Indian Journal of Agricultural Sciences,* 73(8):432-37.

Panwar, R.S.; Malik, R.K.; Balyan, R.S. and Singh, D.P. 1995. *Indian J. of Agricultural Sci.* 65(2): 109-111.

Parihar, G.N.; Singh, R. and Singh, R. 1995. Response of wheat (*Triticum aestivum*) genotypes to seed rate and sowing method under western Rajasthan condition. *Indian J. of Agron.* 40(1): 97-98.

Paul, S.R. 1992. Effect of pre-sowing seed treatment, seed rates, fertility levels and surface soil compaction on growth and yield of late sown rainfed wheat in Assam. *Ann. agric. Res.* 13(4): 410-411.

Pearson, C.J.; Mann, I.G. and Zhang, Z. 1991. Changes in root growth within successive wheat crops in a cropping cycle using minimum and conventional tillage. *Field Crops Res.*, 28: 117-123.

Punia, S.S.; Rathee, S.S. and Malik, R.K. 2003. Effect of fenoxaprop and clodinafop alone and in combination with isoproturon in controlling weeds infesting wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, 73(4): 232-4.

Radford, P.J. 1967. Growth analysis formulae-their use and abuse. *Crop Sci.* 7: 171-175.

Rath, B.S. 1999. Studies on methods of wheat sowing at various levels of puddling in rice under rice-wheat cropping system. Thesis, Ph.D. submitted to G.B. Pant Univ. of Agric. & Tech., Pantnagar.

Reddi, S.G. and Patil, B.N. 2003. Influence of N-levels and seed rates on growth, yield, protein content and N-uptake in wheat genotypes. *Karnataka J. of Agric. Sci.* 16(1): 31-34.

Reinhard, H.; Chervet, A. and Sturny, W.G. 2001. No tillage in field crops. *Revue Suissed' Agriculture*. 33(1): 7-13.

Rorzak, W.; Radecki, A. and Wilkonski, F. 1991. Investigation on possibilities of wring direct sowing under the conditions of central Poland). Badania nad mozliwo's cia zastasowanio sielvu bezpossdniego W. Warunkach Polski Central nej. Roczniki Nank Rolmizych, Sera A. Produkeja Roslinna, 109 (2): 143-156.

Roslon, E. and Fogelfors, H. 2003. Crop and weed growth in a sequence of spring barley and winter wheat crops establishment together from a spring sowing *(Reley cropping). J. of Agron. and Crop Sci.* 189(3): 185-190.

Ruegger, A.; Winzeler, M.; Winzeler, H. 1993. The influence of different nitrogen levels and seeding rates on the dry matter production and nitrogen uptake of spelt (*Triticum spelta* L.) and wheat (*T. aestivum* L.) under field conditions. *J. of Agronomy and Crop Science*. 171(2): 124-132.

Saini, J.P. and Singh, K.P. 2001. Efficacy of new herbicides against grass weeds in wheat (*Triticum aestivum*) under mid-hill conditions of Himachal Pradesh. *Indian Journal of Agronomy,* 46(2): 233-238.

Sen, A.; Pandey, M.D.; Sharma, S.N.; Singh, R.K.; Kumar, A. and Shukla, P. 2003. Surface seeding of wheat (*T. aestivum*) as affected by seed rate and nitrogen level. *Indian J. of Agric. Sci.* 73(9): 509-511.

Sharma, P. 2003. Effect of tillage on soil properties and crop performance in rice-wheat system. Thesis Ph.D. (Soil Science), G.B.P.U.A&T., Pantnagar.

Sharma, R.P. and Malik, C.V.S. 1993. Effect of seed rate, nitrogen and sowing method on yield of late sown wheat (*Triticum aestivum*). *Indian J. Agron.* 38(2): 289-291.

Sharma, S.N. and Prasad, R. 2002. Wheat : In text book of field crop production : 55-58 Ed. By Dr. Rajendra Prasad, ICAR, Publication.

Shaukat, A.; Paigham, S.; Sharif, H.M.; Ali, I. 1999. Yield, yield components and other important agronomic traits of wheat as affected by seed rate and planting geometry. *Sahad J. of Agriculture*. 15(4): 255-262.

Singh, A.K.; Pandey, K.; Singh, S.S. and Thakur, S.S. 1999. Agronomic management for maximizing the productivity of late sown wheat (*Triticum aestivum*). *Indian J. Agron.* 44(2): 357-360.

Singh, D.; Singh, S.P. and Singh, D. 2002. Response of late sown wheat to seed rate and nitrogen. *Progressive Agriculture.* 2(1): 72 p.

Singh, G.; Singh, O.P.; Yadav, R.A. and Singh, R.S. 1993. Response of wheat (*Triticum aestivum*) to planting method, seed rate and fertility in late sown condition. *Indian J. Agron.* 38(2): 195-199.

Singh, G.; Singh, O.P.; Yadava, R.A. and Singh, R.S. 1993. Response of wheat (*T. aestivum*) to planting method, seed rate and fertility in late sown condition. *Indian J. of Agron.* 38(2): 195-199.

Singh, Goriqbal and Brar, S.S. 1994. Tillage and nitrogen requirement of wheat (*Triticum aestivum* L.) sown after rice (*Oryza sativa* L.). *Indian Journal of Agronomy,* 39(1):162-163.

Singh, Govindra; Singh, V.P. and Singh, Mahendra. 2003. Studies on the effect of mesosulfuron and iodosulfuron on weeds in wheat, their compatibility with other chemicals and residual effects on succeeding crops. *Indian J. Weed Sci.* 35(3&4): 173-178.

Singh, Govindra; Singh, V.P.; Singh, Mahendra and Sigh, Rajesh Kr. 2003. Bio-efficacy of fenoxaprop-p-ethyl alone and in combination with isoproturon for control of weeds in wheat. *Indian J. Weed Sci.* 35(3&4): 194-196.

Singh, Govindra; Singh, V.P.; Singh, Mahendra and Singh, Rajesh Kr. 2003. Effect of doses and stages of application of sulfosulfuron on weeds and wheat yield. *Indian J. Weed Sci.* 35(3&4): 183-185.

Singh, Govindra; Singh, V.P.; Singh, Mahendra and Singh, S.P. 2003. Bio-efficacy of Trifluralin alone and in combination with Isoproturon in wheat. *Indian J. Weed Sci.* 35(1&2): 111-113.

Singh, H.; Om Singh; Singh, H. and Singh, O. 1987. Response of late sown wheat to seed rate and nitrogen. *Indian J. Agron.* 32(3): 290-291.

Singh, H.P.; Hooda, R.S.; Malik,P.K.; Yadav, A.K. and Singh, H. 1999. Performance of metribuzin, atrazine, trifluralin and their combinations with isoproturon against weeds in wheat. *Crop Research Hissar.* 17(3): 282-285.

Singh, J.; Malik, R.K.; Kumar, R.; Singh, J. and Kumar, R. 2002. Effect of metribuzin on the mortality of wheat (*T. aestivum* L.) seedlings sown at different seed rates. *Indian J. of Weed Science.* 34(1-2): 119-120.

Singh, K.K. and Gangwar, K.S. 1999. Performance evaluation of conventional sowing, zero till and strip-till drilling of wheat after rice harvesting. *J. Farming Systems Research and Development.* 5(1&2): 66-71.

Singh, L. 2001. Tillage cum herbicide use studies in wheat grown under rice-wheat cropping system. Thesis, Ph.D. (Agron), G.B. Pant Univ. of Agric. & Tech., Pantnagar (U.S. Nagar), p 108-114.

Singh, P.; Aipe, K.C.; Prasad, R.; Sharma, S.N. and Singh, S. 1998. Relative effect of zero and conventional tillage on growth and yield of wheat and soil fertility under rice-wheat system. *Ind. J. Agron.* 43(2): 204-207.

Singh, P.K. and Rafey, A. 1998. Response of wheat (*T. aestivum*) to seeding date, nitrogen levels and seed rate. *J. of Research, Birsa Agricultural Uni.,* 10(1): 34-37.

Singh, Punjab; Aipe, K.C.; Prasad, R.; Sharma, S.N. and Singh, S. 1998. Relative effect of zero and conventional tillage on growth and yield of wheat (*Triticum aestivum*) and soil fertility under rice (*Oryza sativa*) – wheat cropping system. *Indian Journal of Agronomy*, 43(2): 204-207.

Singh, R.P.; Mukherjee, Dhiman; Singh, R.K. and Sinha, A.K. 2003. Bioefficacy of herbicides in late-sown wheat (*Triticum aestivum*). *Indian Journal of Agronomy,* 48(3): 196-198.

Singh, S. 2004. Studies on the development of sustainable direct seeded rice-wheat cropping system. Thesis, Ph.D. submitted to G.B. Pant Univ. of Agric. & Tech., Pantnagar.

Singh, S.J.; Sinha, K.K. Pandey, I.B. and Mishra, S.S. 2000. Cultural and chemical weed control in late sown wheat. *J. of Research Birsa Agricultural University.* 12(2): 249-251.

Singh, S.K. and Saha, G.P. 2001. Productivity and profitability of wheat (*Triticum aestivum*) as influenced by cultural and chemical weed control. *Indian Journal of Agronomy,* 46(3): 475-479.

Singh, T.; Singh, H.; Ram, K.; Faroda, A.S.; Singh, T. and Singh, H. 1988. Concentration and uptake of nitrogen in late sown wheat as affected by seed rate and row spacing. *Indian J. of Agron.* 33(1): 106-108.

Singh, V.P.N. And Uttam, S.K. 1993. Effect of seed rate and inter-row spacing on yield attributes and yield of wheat variety HD-1981 (Pratap) under rainfed condition of Central Uttar Pradesh. *Agricultural Science Digest,* Karnal, 13(3-4): 117-121.

Singh, V.P.N. and Uttam, S.K. 1997. Root development water use and yield of rainfed wheat (*T. aestivum* L.) as influenced by seed rate and sowing method. *Indian J. of Agricultural Research,* 31(2): 136-140.

Singh, Y. and Singh, G. 2004. Zero tillage in rice-wheat cropping systems a technology of global significance. Directorate of Experiment Station, Tech. Bull. No. 137, G.B.P.U.A.&T., Pantnagar-263145, India.

Singh, Y.; Bhardwaj, A.K.; Singh, S.P.; Singh, R.K.; Chaudhary, D.C.; Saxena, Amal; Singh, Vijendra; Singh, Satendra Pal and Abnish Kumar. 2002. Effect of rice (*Oryza sativa*)- establishment methods, tillage practices in wheat (*Triticum aestivum*) and fertilization on soil physical properties and rice-wheat system productivity on a silty clay Mollisol of Uttaranchal. *Indian Journal of Agricultural Sciences,* 72(4): 200-5.

Skorda, E.A.; Zamains, A.T. and Efthiniada, P.G. 1997. Along term study on effect of no tillage on weed development and yield of continuous wheat and barley. Brighton crop Protection Conference Proceeding. International Conference Brighton, U.K. 17-20 Nov. 1997, 3: 997-1002.

Srivastava, R.K.; Sah, D.; Singh, R.; Sah, D. and Singh, R. 2002. Studies on varying mode of tillage operations, seeding rates and fertility levels on yield of wheat var. HUW-234 under puddled rice-wheat sequence. *Research on Crops*, 3(2): 332-334.

Srivastava, U.S.L.; Ram, P.; Prakash, O.; Ram, P. and Prakash, O. 1996. Response of wheat (*T. aestivum*) to row spacing, seed rate and fertilizer. *Indian J. of Agronomy*. 41(4): 558-561.

Srivastava, V.K.; Rajput, R.L. and Sinha, N.K. 1994. Effect of seed rate, fertility levels and weeding on the yield of wheat. *Agricultural Sci. Digest*, Karnal, 14(1): 5-7.

Streist, B.; Stamp, P.; Richner, W.; Haas, Hu (ed.) and Hurle, K. 2000. Impact of different tillage of intensities on weed population in arable crops. Proceedings 20th German Conference on Weed Biology and Weed control, Stuttgart-Hohenheim Germany, 14-16 March, 2000. *Zeitschriftfur-Pflanzenkraukh-eiten-Pflanzenschutz. Sandarh.* 17: 41-46.

Tennant, D. 1975. Ates of modified line intersect method of estimating root length. *J. Ecology*. 63: 995-1001.

Thakur, S.S.; Pandey, I.B. and Mishra, S.S. 1999. Effect of O.M., fertilizer level and seed rate on yield and quality of late-sown wheat (*T. aestivum*). *Indian J. of Agronomy.* 44(4): 754-759.

Thakur, S.S.; Pandey, I.B.; Singh, S.J. and Mishra, S.S. 1996. Effect of seed rate and row spacing on late sown wheat in alluvial calcareous soil. *J. of Research, Birsa Agricultural Univ.* 8(2): 123-125.

The Hindu Survey of Indian Agriculture. 2003.

Tripathi, S.C. and Chauhan, D.S. 2000. Evaluation of fertilizer and seed rate in wheat (*T. aestivum*) under different tillage conditions after transplanted rice (*Oryza sativa*). *Indian J. of Agricultural Sciences*. 70(9): 574-576.

Tripathi, S.C. and Chauhan, D.S. 2001. Effect of tillage and fertilizer on productivity of wheat (*Triticum aestivum*) under dry-seeded and transplanted rice conditions. *Indian Journal of Agronomy,* 46(1): 107-111.

Tripathi, S.C.; Nagarajan, S. and Chauhan, D.S. 1999. Evaluation of zero tillage in wheat (*Triticum aestivum*) under different methods of rice (*Oryza sativa*) transplanting. *Indian Journal of Agronomy*, 44(2): 219-222.

Tuesca, D.; Puricelli, E. and Papa, J. 2001. A long-term study of weed flora shifts in different tillage systems. *Weed Research Oxford.* 41(4): 369-382.

Turley, D.B. 1999. Effect of seed rate on tillering and yield of wheat cultivars. *Tests of Agrochemicals and Cultivars.* No.20: 64-65.

Upadhyay, V.B. and Tiwari, J.P. 1996. Influence of nitrogen, seed rate and mulch on wheat (*Triticum aestivum*) varieties under late sown conditions. *Indian J. Agron.* 41(4): 562-565.

Verma, U.N. and Srivastva, V.C. 1989. Weed management in wheat after zero and optimum-tillage conditions. *Indian J. Agron.*, 34: 199.

Walia, U.S.; Brar, L.S. and Dhaliwal, B.K. 1997. Resistance to isoproturon in *Phalaris minor* in Punjab. *Plant Protection Quarterly.* 12: 138-140.

Walia, V.S.; Kaur, R.; Kumar, N.; Kaur, R. and Kumar, N. 2000. N uptake by wheat and *Phalaris minor* as influenced by irrigation and weed control treatments. *Environment and Ecology.* 18(1): 134-137.

William F. Schillinger. 2001. Minimum and delayed conservation tillage for wheat-fallow farming. *Soil Sci. Soc. Am. J.* 65: 1203-1209.

Wood, G.A.; Welsh, J.P.; Godwin, R.J.; Taylor, J.C.; Earl, R. and Knight, S.M. 2003. Real time measures of canopy size as a basis for spatially varying nitrogen applications to winter wheat sown at different seed rates. *Biosystems Engineering.* 84(4): 513-531.

Workayehu, T. and Workayehu, T. 2000. Response of weed infestation and grain yield and wheat to frequency of tillage and weed control method under rainfed conditions at Arsi Negelle, Ethiopia. The Eleventh Regional Wheat Workshop for eastern, Central and Southern Africa, Addis Ababa, Ethiopia, 18-22 Sept. 2000. 370-379.

APPENDICES

APPENDIX-Ia

Week wise weather data for the crop period from November, 2002 to April, 2003 at Pantnagar

Meteoro-logical week no.	Month and date	Temperature (^0C)		Relative humidity (%) At		Total rainfall (mm)	Bright sunshine (hrs)	Wind speed (km hr^{-1})	Pan evaporation (mm day^{-1})
		Max.	Min.	7.00 AM	2.00 PM				
46	Nov. 12-18	27.0	11.7	90	43	0.0	8.5	3.0	3.3
47	19-25	27.0	10.4	90	35	0.0	8.2	1.3	2.7
48	26-2D	26.8	8.2	93	36	0.0	9.1	1.0	2.5
49	Dec. 03-09	25.0	7.5	92	41	0.0	8.0	1.4	2.8
50	10-16	23.9	7.7	93	43	0.0	8.0	1.5	2.3
51	17-23	23.5	7.7	93	51	0.0	5.7	2.7	2.2
52	24-31	18.8	7.6	95	67	63.0	4.7	4.0	2.2
1	Jan. 01-7J	15.1	8.0	95	76	0.0	3.9	2.9	1.3
2	08-14	11.1	6.0	96	81	0.0	2.1	2.7	0.9
3	15-21	13.3	5.6	96	79	0.0	2.2	2.7	0.9
4	22-28	17.4	5.5	99	74	10.2	3.3	3.0	1.2
5	29-4F	19.3	9.0	95	69	22.2	5.5	4.5	1.6
6	Feb.05-11	22.7	7.4	91	64	0.0	7.8	1.8	2.1
7	12-18	21.7	8.3	90	56	42.8	5.5	4.2	3.1
8	19-25	21.8	8.9	94	61	15.6	8.4	3.9	2.8
9	26-4M	24.2	11.4	91	58	9.8	6.6	4.7	3.1
10	Mar. 05-11	24.1	7.7	92	49	0.0	9.7	4.7	2.9
11	12-18	27.5	13.5	87	48	0.0	7.3	3.5	3.3
12	19-25	28.8	13.6	84	46	9.0	8.2	4.2	4.0
13	26-1A	30.6	15.3	86	41	Trace	8.4	4.1	4.2
14	April 02-08	32.7	14.8	80	29	0.4	8.3	4.6	5.3
15	09-15	37.2	17.5	76	21	0.0	10.2	3.9	6.8
16	16-22	37.0	18.1	65	23	1.2	9.9	5.0	6.9

APPENDIX-Ib

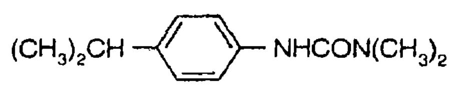
Weak wise weather data for the crop period from November, 2003 to April, 2004 at Pantnagar

Meteorological week no.	Month and date	Temperature (°C)		Relative humidity (%) at		Total rainfall (mm)	Bright sunshine (hrs)	Wind speed (km hr^{-1})	Pan evaporation (mm day^{-1})
		Max.	Min.	7.00 AM	2.00 PM				
48	26-2D	24.5	6.8	93	40	0.0	8.4	1.1	1.8
49	Dec.03-09	23.4	8.1	93	49	0.0	4.9	1.5	1.3
50	10-16	24.8	11.0	87	50	14.4	6.2	3.7	2.1
51	17-23	19.0	9.2	93	66	0.0	3.2	3.1	1.1
52	24-31	15.2	7.5	93	72	4.2	3.0	3.0	1.2
1	Jan. 01-7J	14.6	7.5	93	72	0.0	1.6	2.6	0.9
2	08-14	18.3	5.8	97	62	0.0	5.1	2.1	0.9
3	15-21	18.6	8.9	93	71	0.0	3.7	3.3	1.1
4	22-28	17.9	7.5	96	65	16.4	4.1	4.0	1.2
5	29-4F	17.3	7.7	95	70	13.2	3.0	4.1	1.3
6	Feb. 05-11	20.8	6.9	94	52	0.0	7.2	2.6	1.4
7	12-18	25.1	9.3	88	48	0.0	8.2	2.0	2.0
8	19-25	25.3	9.9	88	55	0.0	8.9	3.1	2.6
9	26-4M	27.2	10.2	87	44	0.0	9.2	6.1	3.6
10	Mar. 05-11	28.6	10.9	81	33	0.0	9.8	4.5	4.0
11	12-18	30.9	15.7	87	48	0.0	8.3	2.3	3.3
12	19-25	34.6	15.8	83	27	0.0	9.0	5.3	5.9
13	26-1A	34.7	14.3	80	18	0.0	10.1	4.0	5.5
14	April 02-08	36.1	18.1	71	28	0.0	8.4	4.1	6.3
15	09-15	38.4	18.5	64	17	0.0	9.7	6.4	8.7

APPENDIX-II

isoproturon

HRAC C_2 WSSA 7: urea



NOMENCLATURE: Common name isoproturon (BSI, E-ISO, (*m*) F-ISO)
IUPAC name 3-(4-isopropylphenyl)-1,1-dimethylurea; 3-*p*-cumenyl-1,1-dimethylurea
Chemical Abstracts name *N,N*-dimethyl-*N'*-[4-(1-methylethyl)phenyl]urea
Other names IPU; ipuron* **CAS RN** *[34123-59-6]* **EEC no.** 251-835-4
Development codes Hoe 16410; AE F016410; CGA 18 731; 35689 RP; LS 6912999

PHYSICAL CHEMISTRY: **Composition** Tech. is ≥98.5% pure. **Mol. wt.** 206.3 **M.f.** $C_{12}H_{18}N_2O$ **Form** Colourless crystals. **M.p.** 158 °C; (tech., 153–156 °C) **V.p.** 3.15×10^{-3} mPa (20 °C); 8.1×10^{-3} mPa (25 °C) K_{ow} logP = 2.5 (20 °C) **Henry** 1.46×10^{-5} Pa m^3 mol^{-1} **S.g./density** 1.2 (20 °C) **Solubility** In water 65 mg/l (22 °C). In methanol 75, dichloromethane 63, acetone 38, benzene 5, xylol 4, *n*-hexane c. 0.2 (all in g/l, 20 °C). **Stability** Very stable to light, acids, and alkalis. Hydrolytically cleaved by strong alkalis on heating.

COMMERCIALISATION: **History** Herbicide introduced by Ciba-Geigy AG (now Novartis Crop Protection AG, who no longer manufacture or market it), Hoechst AG and Rhône-Poulenc Agrochimie (both now Aventis CropScience). **Patents** GB 1407587 to Ciba-Geigy **Manufacturers** Atul; Aventis; ÉMV; Gharda; Griffin; Jiangsu; Makhteshim-Agan; United Phosphorus.

APPLICATIONS: **Biochemistry** Photosynthetic electron transport inhibitor at the photosystem II receptor site. **Mode of action** Selective systemic herbicide, absorbed by the roots and leaves, with translocation. **Uses** Pre- and post-emergence control of annual grasses (*Alopecurus myosuroides, Apera spica-venti, Avena fatua* and *Poa annua*) and many annual broad-leaved weeds in spring and winter wheat (except durum wheat), spring and winter barley, winter rye, and triticale, at 1.0–1.5 kg a.i./ha. **Phytotoxicity** Non-phytotoxic to cereals, except durum wheats. **Formulation types** SC; WP. **Selected tradenames** 'Alon' (Aventis); 'Arelon' (Aventis); 'Strong' (Aventis); 'Tolkan' (Aventis); 'Cordelia' (Griffin); 'Dhanulon' (Dhanuka); 'Guideline' (Barclay); 'Hilproturon' (Hindustan); 'Iprofile' (Mirfield); 'Isoguard' (Gharda); 'Narilon' (Nagarjuna Agrichem); 'Panron' (Sanonda); 'Pasport' (RPG); 'Protugan' (Makhteshim-Agan); 'Turonex' (Agriphar); **mixtures** 'Javelin' (+ diflufenican) (Aventis); 'Affinity' (+ carfentrazone-ethyl) (FMC); 'Herbaflex' (+ beflubutamid) (Staehler, Ube)

ANALYSIS: Product analysis by hplc (*CIPAC Handbook*, 1992, **E**, 110–115; *Anal. Methods Pestic. Plant Growth Regul.*, 1982, **12**) or by titration of the dimethylamine liberated on hydrolysis. **Residues** determined by glc (*Man. Pestic. Anal.* Deutsche Forschungsgemeinschaft, 1978, **1**, 241; Anal. Methods of Pesticide Residues in Foodstuffs, General Inspectorate for Health Protection, Netherlands, June 1996).

MAMMALIAN TOXICOLOGY: **Oral** Acute oral LD_{50} for rats 1826–2417, mice 3350 mg/kg. **Skin and eye** Acute percutaneous LD_{50} for rats >2000 mg/kg. Non-irritating to skin and eyes (rabbits). **Inhalation** LC_{50} (4 h) for rats >1.95 mg/l air. **NOEL** (90 d) for rats 400, dogs 50 mg/kg diet; (2 y) for rats 80 mg/kg diet. **ADI** 0.0062 mg/kg b.w. **Water GV** 9 μg/l (TDI 3 μg/kg b.w.). **Toxicity class** WHO (a.i.) III **EC hazard** R40| Xn; R22| N; R50, R53

ECOTOXICOLOGY: **Birds** Acute oral LD_{50} for Japanese quail 3042–7926, pigeons >5000 mg/kg. **Fish** LC_{50} (96 h) for golden orfe 129, bluegill sunfish >100, guppies 90, rainbow trout 37, carp 193, catfish 9 mg/l. **Daphnia** LC_{50} (48 h) 507 mg/l. **Algae** LC_{50} (72 h) 0.03 mg/l. **Bees** Not toxic to bees; LD_{50} (48 h, oral) >50–>100 μg/bee. **Worms** LC_{50} (14 d) for *Eisenia foetida* >1000 mg/kg dry artificial soil. **Other beneficial spp.** A dose of up to 1.5 kg/ha (as 'Arelon') was harmless to adult female *Aleochara bilineata*.

ENVIRONMENTAL FATE: **Animals** In rats, following oral administration, 50% is eliminated within the first 8 h, predominantly in the urine. **Plants** In plants, degradation is mainly via hydroxylation of the isopropyl group to 1,1-dimethyl-3-[4-(2'-hydroxy-2'-propyl)phenyl]urea; *N*-dealkylation also occurs. **Soil/Environment** Undergoes enzymic and microbial demethylation at the nitrogen, and hydrolysis of the phenylurea to 4-isopropylaniline. DT_{50} in soil 6–28 d; rate of degradation increases 3x between 10 °C and 30 °C (sandy soil) and 10x in an organic soil over the same temperature range.

APPENDIX-III

Analysis of variance showing mean square for plant stand (m^{-2}) at 20 days after sowing

Source of variation	Degree of freedom	Plant stand	
		2002-03	2003-04
Replication	2	5092	1080
Tillage	1	17703**	11546**
Seed rate	2	37334**	38556**
Tillage x Seed rate	2	1176	1589
Error (a)	10	514	552
Weed control method	3	1062	559
Tillage x Weed control method	3	38	143
Seed rate x Weed control method	6	243	94
Tillage x Seed rate x Weed control method	6	144	119
Error (b)	36	741	516
Total	71	2005	1711

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-IV

Analysis of variance showing mean square for number of shoots (m^{-2}) at various growth stages

Source of variation	Degree of freedom	Number of shoot (m^{-2})							
		Days after sowing (DAS)							
		2002-03				2003-04			
		30	60	90	120	30	60	90	120
Replication	2	8626	19888	21659	20253	1253	3666	4822	6794
Tillage	1	144130**	102211**	49037**	48027**	16230*	18768*	38375*	28978*
Seed rate	2	188372**	176181**	82303**	60832**	104737**	61310**	58393**	39260**
Tillage x Seed rate	2	7532	558	383	1183	1479	601	3998	710
Error (a)	10	5814	5190	3917	2385	2293	3179	4687	3368
Weed control method	3	2453	12976*	15940*	13382*	1308	8971*	13353*	12574**
Tillage x Weed control method	3	1165	3627	12132	6944	939	1198	3960	3546
Seed rate x Weed control method	6	95	1788	6407	4392	350	770	6413	4240
Tillage x Seed rate x Weed control method	6	1093	3180	8251	3663	162	1165	6675	4655
Error (b)	36	1687	3503	5526	4243	882	1994	3583	2429
Total	71	9719	10607	9408	7021	4164	4164	6749	4864

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-V

Analysis of variance showing mean square for plant height (cm) at various growth stages

Source of variation	Degree of freedom	Plant height (cm)							
		Days after sowing (DAS)							
		2002-03				2003-04			
		30	60	90	120	30	60	90	120
Replication	2	56.27	68.54	30.94	43.65	16.71	48.61	17.38	8.64
Tillage	1	48.68	76.47	22.56	36.98	40.05**	42.94	12.33	79.80**
Seed rate	2	26.35	16.03	10.80	5.58	7.75	16.83	28.62	16.56*
Tillage x Seed rate	2	1.05	1.30	15.13	0.86	16.30*	63.87	3.25	11.01
Error (a)	10	10.06	20.61	11.66	9.15	3.17	20.26	7.94	4.99
Weed control method	3	1.45	5.96	9.96	11.77*	0.81	4.03	14.29	25.72*
Tillage x Weed control method	3	0.48	2.86	6.24	12.79	1.03	8.18	7.00	1.71
Seed rate x Weed control method	6	5.50	10.84	7.99	8.60	2.00	26.28	15.29	6.39
Tillage x Seed rate x Weed control method	6	5.23	10.91	9.76	1.62	2.91	13.41	11.12	14.95
Error (b)	36	6.23	7.24	6.33	4.89	2.80	15.99	12.93	12.17
Total	71	8.61	12.28	8.95	7.60	4.07	19.08	12.37	11.98

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-VI

Analysis of variance showing mean square for leaf area index (LAI) at various growth stages

Source of variation	Degree of freedom	Leaf area index (LAI)							
		Days after sowing (DAS)							
		2002-03				2003-04			
		30	60	90	120	30	60	90	120
Replication	2	0.090	1.385	2.902	0.395	0.0048	0.376	0.513	-
Tillage	1	1.981**	20.68**	3.409	0.130	0.0000035	0.00039	0.769	-
Seed rate	2	1.755**	10.26**	2.207*	0.059	1.238**	14.80**	18.80**	-
Tillage x Seed rate	2	0.405	1.655	0.621	0.656	0.0039	0.475	4.708	-
Error (a)	10	0.041	0.562	0.846	0.045	0.016	0.375	0.427	-
Weed control method	3	0.0069	3.697**	13.52**	1.088**	0.0025	2.955**	12.41**	-
Tillage x Weed control method	3	0.050	1.349	3.940	0.560	0.040	0.838	0.228	-
Seed rate x Weed control method	6	0.028	0.328	1.742	0.373	0.035	0.730	1.724	-
Tillage x Seed rate x Weed control method	6	0.121	0.365	3.918	0.402	0.014	0.988	1.199	-
Error (b)	36	0.015	0.261	0.567	0.050	0.0086	0.439	0.409	-
Total	71	0.120	1.149	1.832	0.200	0.048	1.022	1.736	-

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-VII

Analysis of variance showing mean square for plant dry weight (g m^{-2}) at various growth stages

Source of variation	Degree of freedom	Plant dry weight (g m^{-2})							
		Days after sowing (DAS)							
		2002-03				2003-04			
		30	60	90	120	30	60	90	120
Replication	2	82	7570	24440	669408	52	86	7657	23925
Tillage	1	614*	4663	129959	76080	614**	1107	1923	144
Seed rate	2	963**	24872**	28316	64955	962**	3139*	14343	12666
Tillage x Seed rate	2	85	3195	5599	78073	86	356	12551	40829
Error (a)	10	76	1915	32447	101389	35	603	18520	57147
Weed control method	3	21	38299**	283522**	274489**	14**	2103**	91728**	83789*
Tillage x Weed control method	3	135**	236	26079	5151	135**	54	2148	31304
Seed rate x Weed control method	6	44	3349	14161	39896	44	107	7223	15499
Tillage x Seed rate x Weed control method	6	29	763	12313	10348	29	140	3720	23881
Error (b)	36	28	1407	21448	54579	14	177	8172	28272
Total	71	78	4028	34238	81973	64	403	12644	32758

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-VIII

Analysis of variance showing mean square for mean crop growth rate (g day^{-1} m^{-2}) at various growth stages

Source of variation	Degree of freedom	Mean crop growth rate (g day^{-1} m^{-2})					
		Days stages					
		2002-03			2003-04		
		30-60	60-90	90-120	30-60	60-90	90-120
Replication	2	10.12	20.00	16.13	0.24	7.02	5.04
Tillage	1	2.10	94.87	8.00	0.08	0.12	1.13
Seed rate	2	18.30**	0.31	37.83	0.71	4.79	1.86
Tillage x Seed rate	2	3.19	0.95	89.16	0.57	18.75	35.43
Error (a)	10	1.88	34.93	10.91	0.71	22.01	13.41
Weed control method	3	42.54**	136.8**	19.81	2.31**	74.32**	0.61
Tillage x Weed control method	3	0.068	31.91	59.91	0.19	2.30	49.18
Seed rate x Weed control method	6	3.09	19.05	55.53	0.10	7.62	31.57
Tillage x Seed rate x Weed control method	6	0.65	14.69	41.40	0.28	4.33	27.08
Error (b)	36	1.52	29.13	6.95	0.20	9.74	11.68
Total	71	4.07	31.61	20.77	0.39	13.15	16.08

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-IX

Analysis of variance showing mean square for mean relative growth rate ($g\ g^{-1}\ day^{-1}\ m^{-2}$) at various growth stages

Source of variation	Degree of freedom	Mean relative growth rate ($g\ g^{-1}\ day^{-1}\ m^{-2}$)					
		Days stages					
		2002-03			2003-04		
		30-60	60-90	90-120	30-60	60-90	90-120
Replication	2	0.000301	0.000077	0.000258	0.000073	0.000005	0.000015
Tillage	1	0.000175	0.000024	0.000023	0.000260*	0.000018	0.000004
Seed rate	2	0.000109	0.000144	0.000030	0.000311*	0.000043	0.000006
Tillage x Seed rate	2	0.000039	0.000026	0.000057	0.000124	0.000081	0.000036
Error (a)	10	0.000048	0.000055	0.000094	0.000051	0.000069	0.000090
Weed control method	3	0.000558**	0.000055	0.000040	0.000119**	0.000022	0.000023
Tillage x Weed control method	3	0.000076	0.000050	0.000053	0.000144**	0.000008	0.000056
Seed rate x Weed control method	6	0.000016	0.000043	0.000038	0.000035	0.000017	0.000036
Tillage x Seed rate x Weed control method	6	0.000012	0.000035	0.000046	0.000054	0.000013	0.000025
Error (b)	36	0.000037	0.000058	0.000056	0.000019	0.000027	0.000044
Total	71	0.000070	0.000055	0.000063	0.000053	0.000031	0.000045

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-X

Analysis of variance showing mean square for development stages (days)

Source of variation	Degree of freedom	Development stages (days)					
		Heading		Maturity		Reproductive period	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	2.38	1.93	7.76	7.12	3.85	4.68
Tillage	1	6.13	4.50	156.1**	60.50**	224.0**	98.00**
Seed rate	2	8.15*	1.74	51.03**	26.08**	18.90*	15.37*
Tillage x Seed rate	2	1.12	0.54	2.06	1.79	2.93	2.04
Error (a)	10	1.82	1.45	1.30	1.06	2.73	2.10
Weed control method	3	8.05*	4.59*	45.65**	14.12**	16.47**	4.22*
Tillage x Weed control method	3	0.83	0.61	0.20	0.24	0.35	0.33
Seed rate x Weed control method	6	0.27	0.26	1.41	1.15	1.99	1.63
Tillage x Seed rate x Weed control method	6	1.33	0.99	0.81	0.75	3.49	2.54
Error (b)	36	2.31	1.81	0.86	0.72	2.69	2.08
Total	71	2.35	1.63	6.65	3.12	6.80	3.90

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XI

Analysis of variance showing mean square for number of spikes (m^{-2})

Source of variation	Degree of freedom	Number of spikes (m^{-2})	
		2002-03	2003-04
Replication	2	31953	6131
Tillage	1	41728**	29516*
Seed rate	2	55798**	30306**
Tillage x Seed rate	2	725	362
Error (a)	10	3318	3635
Weed control method	3	15989*	12466**
Tillage x Weed control method	3	6352	2757
Seed rate x Weed control method	6	3931	4014
Tillage x Seed rate x Weed control method	6	3434	4138
Error (b)	36	4726	2374
Total	71	7510	4500

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XII

Analysis of variance showing mean square for spike length (cm), fertile spikelets spike^{-1} and sterile spikelets spike^{-1}

Source of variation	Degree of freedom	Spike length (cm)		Fertile spikelets spike^{-1}		Sterile spikelets spike^{-1}	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	0.309	1.231	3.522	3.695	0.491	1.496
Tillage	1	0.095	4.215	0.168	30.681**	0.020	0.142
Seed rate	2	1.164**	0.930	1.727	0.740	0.201	0.062
Tillage x Seed rate	2	0.415	0.199	0.560	0.202	0.902	0.602*
Error (a)	10	0.302	1.559	1.596	2.151	0.953	0.104
Weed control method	3	0.072	0.078	0.353	1.149	0.889	0.386
Tillage x Weed control method	3	0.105	0.352	1.952	1.224	1.873	0.203
Seed rate x Weed control method	6	0.567	0.488	1.265	1.944	0.960	0.361
Tillage x Seed rate x Weed control method	6	0.608	0.864	1.491	1.993	1.226	0.539**
Error (b)	36	0.880	0.419	2.500	2.143	1.667	0.171
Total	71	0.650	0.690	1.989	2.385	1.326	0.265

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XIII

Analysis of variance showing mean square for number of grains spike^{-1}, grain weight spike^{-1} (g) and 1000-grain weight (g)

Source of variation	Degree of freedom	Number of grains spike^{-1}		Grain weight spike^{-1} (g)		1000-grain weight (g)	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	68.19	27.21	0.099	0.030	3.10	3.71
Tillage	1	28.00	16.53	0.159	0.137	17.42	21.46
Seed rate	2	19.61	20.24	0.027	0.110	1.89	3.25
Tillage x Seed rate	2	39.24	3.72	0.074	0.073	2.68	5.03
Error (a)	10	47.55	33.79	0.070	0.095	4.16	5.98
Weed control method	3	45.33	53.26	0.065	0.183*	2.62	4.92
Tillage x Weed control method	3	45.14	36.17	0.161	0.188*	3.44	2.78
Seed rate x Weed control method	6	9.93	11.00	0.059	0.058	3.78	1.23
Tillage x Seed rate x Weed control method	6	59.94	35.09	0.064	0.028	4.33	2.93
Error (b)	36	70.98	34.88	0.104	0.062	11.20	4.35
Total	71	56.39	31.79	0.090	0.076	7.67	4.36

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XIV

Analysis of variance showing mean square for biological yield (kg ha^{-1}), grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and grain-straw ratio

Source of variation	Degree of freedom	Biological yield (kg ha^{-1})		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Grain-straw ratio	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	2169778	1103248	361216	204773	1755229	385110	0.0112	0.0038
Tillage	1	280938	38249	1504447	677407	485145	393806	0.0336	0.0171
Seed rate	2	965491	1332531	291032	352033	198578	413645	0.0012	0.0032
Tillage x Seed rate	2	1018793	800312	84030	15297	1432855	947359	0.0093	0.0046
Error (a)	10	1341770	975027	361505	148887	1334236	968012	0.0128	0.0102
Weed control method	3	11046687**	8583130**	7598176**	4091470**	375306	1474157**	0.0736**	0.0503**
Tillage x Weed control method	3	23899	128262	76167	204702	77866	382735	0.0034	0.0086*
Seed rate x Weed control method	6	194228	26112	25713	26164	156426	48311	0.0012	0.0012
Tillage x Seed rate x Weed control method	6	295280	28845	7078	723	268434	25348	0.0010	0.0001
Error (b)	36	537576	389396	140631	83156	741906	292856	0.0072	0.0025
Total	71	1091666	799196	491191	272591	721382	424248	0.0100	0.0059

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XV

Analysis of variance showing mean square for weed density (no. m^{-2}) at various growth stages

Source of variation	Degree of freedom	Weed density (no. m^{-2}) Days after sowing (DAS) 2002-03				2003-04			
		30	60	90	120	30	60	90	120
Replication	2	0.010	0.034	0.220	0.278	0.123	0.184	0.413	0.255
Tillage	1	2.506**	0.309	0.021	0.343	2.011**	0.687*	0.00076	2.795**
Seed rate	2	0.005	0.062	0.296*	0.407	0.009	0.154	0.278	0.721*
Tillage x Seed rate	2	0.0025	0.00044	0.0034	0.005	0.0005	0.00045	0.026	0.030
Error (a)	10	0.056	0.132	0.090	0.205	0.047	0.081	0.217	0.098
Weed control method	3	158.62**	133.12**	124.79**	96.60**	154.35**	136.94**	119.31**	71.25**
Tillage x Weed control method	3	0.281*	0.248*	0.101	0.044	0.227*	0.190**	0.240*	0.318**
Seed rate x Weed control method	6	0.003	0.012	0.047	0.085	0.0029	0.038	0.059	0.182*
Tillage x Seed rate x Weed control method	6	0.0069	0.00075	0.0016	0.0047	0.0083	0.00043	0.0062	0.009
Error (b)	36	0.067	0.065	0.059	0.166	0.075	0.035	0.081	0.062
Total	71	6.792	5.695	5.338	4.229	6.609	5.846	5.149	3.153

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XVI

Analysis of variance showing mean square for weed dry weight (g m^{-2}) at various growth stages

Source of variation	Degree of freedom	Weed dry weight (g m^{-2}) Days after sowing (DAS)							
		2002-03				2003-04			
		30	60	90	120	30	60	90	120
Replication	2	0.013	0.012	0.0046	0.016	0.053	0.019	0.00078	0.0083
Tillage	1	0.525**	0.302**	0.593**	10.044**	0.278*	0.022	0.911**	15.995**
Seed rate	2	0.029	0.157**	0.164*	0.116*	0.020	0.174*	0.202**	0.314**
Tillage x Seed rate	2	0.00043	0.00033	0.0017	0.0085	0.00033	0.00018	0.0035	0.010
Error (a)	10	0.016	0.0094	0.021	0.017	0.028	0.023	0.0068	0.034
Weed control method	3	45.828**	75.202**	93.455**	81.942**	42.126**	76.877**	91.407**	66.626**
Tillage x Weed control method	3	0.059	0.444**	0.074**	1.118**	0.031	0.291**	0.122**	1.819**
Seed rate x Weed control method	6	0.0046	0.022	0.023	0.017	0.0036	0.025	0.031	0.073
Tillage x Seed rate x Weed control method	6	0.0032	0.00031	0.00025	0.0015	0.0040	0.00017	0.0005	0.0095
Error (b)	36	0.019	0.021	0.011	0.015	0.015	0.014	0.016	0.035
Total	71	1.960	3.219	3.975	3.666	1.800	3.279	3.898	3.156

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XVII

Analysis of variance showing mean square for weed control efficiency (%)

Source of variation	Degree of freedom	Weed control efficiency (%)					
		Days after sowing (DAS)					
		2002-03			2003-04		
		60	90	120	60	90	120
Replication	2	5.92	0.0074	0.13	11.38	4.81	6.43
Tillage	1	1147.06**	35.37	16.79	710.33**	80.65*	85.07
Seed rate	2	12.45	17.62	4.39	11.40	22.42	27.05
Tillage x Seed rate	2	16.86	0.23	1.13	0.59	0.13	4.94
Error (a)	10	11.26	17.17	36.25	35.42	10.54	19.56
Weed control method	3	36289.02**	33181.01**	34209.71**	35261.96**	34032.97**	36322.33**
Tillage x Weed control method	3	497.36**	18.96	6.54	376.97**	32.06	29.04
Seed rate x Weed control method	6	16.40	5.98	2.19	4.07	7.52	9.33
Tillage x Seed rate x Weed control method	6	143.20**	0.10	0.38	0.32	0.08	4.91
Error (b)	36	35.34	27.87	38.26	36.86	32.92	44.57
Total	71	1604.50	1420.88	1470.87	1540.58	1460.09	1564.81

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XVIII

Analysis of variance showing mean square for crop-weed competition index

Source of variation	Degree of freedom	Crop-weed competition index	
		2002-03	2003-04
Replication	2	3.33	2.00
Tillage	1	85.14**	537.07**
Seed rate	2	51.55*	98.19*
Tillage x Seed rate	2	25.95	2.02
Error (a)	10	13.16	15.52
Weed control method	3	2218.92**	2360.71**
Tillage x Weed control method	3	22.39*	121.33**
Seed rate x Weed control method	6	10.19	16.44
Tillage x Seed rate x Weed control method	6	4.13	0.54
Error (b)	36	7.89	8.09
Total	71	105.24	123.04

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XIX

Analysis of variance showing mean square for nitrogen content (%) in grain and straw

Source of variation	Degree of freedom	Nitrogen content (%)			
		Grain		Straw	
		2002-03	2003-04	2002-03	2003-04
Replication	2	0.0714	0.0330	0.0063	0.0039
Tillage	1	0.6687*	0.4226*	0.0212*	0.0115**
Seed rate	2	0.2099	0.1746	0.0063	0.0064*
Tillage x Seed rate	2	0.3207	0.0278	0.0004	0.0011
Error (a)	10	0.0963	0.0606	0.0033	0.0009
Weed control method	3	0.4044**	0.3968**	0.0645**	0.0625**
Tillage x Weed control method	3	0.0112	0.0088	0.00065	0.00048
Seed rate x Weed control method	6	0.0010	0.0030	0.00023	0.00031
Tillage x Seed rate x Weed control method	6	0.0148	0.0111	0.00041	0.00039
Error (b)	36	0.0324	0.0231	0.00052	0.00036
Total	71	0.0753	0.0512	0.0042	0.0035

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XX

Analysis of variance showing mean square for phosphorus content (%) in grain and straw

Source of variation	Degree of freedom	Phosphorus content (%)			
		Grain		Straw	
		2002-03	2003-04	2002-03	2003-04
Replication	2	0.000234	0.000186	0.000031	0.000052
Tillage	1	0.000897**	0.000682**	0.000188**	0.000138*
Seed rate	2	0.000626**	0.000924**	0.000083*	0.000163**
Tillage x Seed rate	2	0.000042	0.000031	0.000006	0.000000
Error (a)	10	0.000070	0.000064	0.000011	0.000018
Weed control method	3	0.000661**	0.000691**	0.000205**	0.000218**
Tillage x Weed control method	3	0.000280	0.000042	1.32E-16	0.00000010
Seed rate x Weed control method	6	0.000146	0.000110	0.00000113	0.00000080
Tillage x Seed rate x Weed control method	6	0.000175	0.000081	9.25E-18	0.00000008
Error (b)	36	0.000128	0.000057	0.000008	0.000014
Total	71	0.000180	0.000127	0.000020	0.000027

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XXI

Analysis of variance showing mean square for potassium content (%) in grain and straw

Source of variation	Degree of freedom	Potassium content (%)			
		Grain		Straw	
		2002-03	2003-04	2002-03	2003-04
Replication	2	0.00928	0.00483	0.0048	0.0043
Tillage	1	0.00089	0.00179	0.0424	0.0777
Seed rate	2	0.00040	0.00052	0.0398	0.0401
Tillage x Seed rate	2	0.00177	0.00197	0.0062	0.0065
Error (a)	10	0.00178	0.00117	0.0335	0.0165
Weed control method	3	0.00031	0.00064	0.0998**	0.1048**
Tillage x Weed control method	3	0.00039	0.00045	0.0019	0.0014
Seed rate x Weed control method	6	0.00075	0.00038	0.0060	0.0066
Tillage x Seed rate x Weed control method	6	0.00114	0.00047	0.0154	0.0153
Error (b)	36	0.00052	0.00046	0.0132	0.0066
Total	71	0.00104	0.00075	0.0196	0.0146

* *Significant at 5 % level*
** Significant at 1 % level

APPENDIX-XXII

Analysis of variance showing mean square for nitrogen, phosphorus and potassium uptake (kg ha^{-1}) by wheat at harvest

Source of variation	Degree of freedom	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	321.6	202.3	3.102	0.723	387.2	308.9
Tillage	1	1404.1	433.1	0.0027	0.0068	170.4	222.9
Seed rate	2	431.4	92.8	1.064	0.268	83.0	75.3
Tillage x Seed rate	2	823.1	112.3	0.314	0.493	501.9	393.1
Error (a)	10	339.3	108.1	0.940	0.520	480.0	300.1
Weed control method	3	7296.1**	4533.3**	83.662**	50.906**	2345.9**	2245.8**
Tillage x Weed control method	3	61.7	73.3	1.357	0.829	2.9	25.0
Seed rate x Weed control method	6	30.2	12.6	0.638	0.293	102.6	60.0
Tillage x Seed rate x Weed control method	6	56.9	15.0	0.972	0.139	228.3	84.2
Error (b)	36	92.7	38.0	0.677	0.369	175.5	97.5
Total	71	477.2	249.1	4.330	2.525	313.6	224.9

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XXIII

Analysis of variance showing mean square for nitrogen, phosphorus and potassium removal (kg ha^{-1}) by weeds at 60 DAS

Source of variation	Degree of freedom	Nitrogen removal (kg ha^{-1})		Phosphorus removal (kg ha^{-1})		Potassium removal (kg ha^{-1})	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	0.037	3.130	0.004	0.345	0.049	4.055
Tillage	1	2.148	14.534	0.310	1.756	3.016	19.280
Seed rate	2	10.608*	13.233*	1.148*	1.428*	13.652*	17.009*
Tillage x Seed rate	2	0.011	0.011	0.001	0.001	0.014	0.014
Error (a)	10	2.663	3.585	0.303	0.400	3.484	4.661
Weed control method	3	1593.9**	1665.0**	181.6**	189.7**	2085.6**	2179.2**
Tillage x Weed control method	3	55.203**	63.553**	6.074**	7.060**	71.539**	82.577**
Seed rate x Weed control method	6	2.403	2.676	0.273	0.303	3.146	3.502
Tillage x Seed rate x Weed control method	6	0.076	0.076	0.0081	0.0081	0.098	0.098
Error (b)	36	3.612	3.301	0.403	0.370	4.695	4.296
Total	71	72.426	76.114	8.236	8.660	94.722	99.573

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XXIV

Analysis of variance showing mean square for cost of cultivation (Rs.ha^{-1}), gross return (Rs.ha^{-1}), net return (Rs.ha^{-1}) and net return per rupee invested (Rs.)

Source of variation	Degree of freedom	Cost of cultivation (Rs.ha^{-1})		Gross return (Rs.ha^{-1})		Net return (Rs.ha^{-1})		Net return per rupee invested (Rs.)	
		2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Replication	2	0	0	25150906	9586263	25150906	9586263	0.1084	0.0337
Tillage	1	44935200	44935200	41910675	16457594*	52683	7004366	0.9526**	0.3536**
Seed rate	2	10935000	24000000	17649911	21738796**	7705743	6493691	0.2526**	0.1565**
Tillage x Seed rate	2	0	0	1959480	1830974	1959480	1830974	0.0089	0.0081
Error (a)	10	0	0	9235445	2587271	9235445	2587271	0.0409	0.0080
Weed control method	3	27898050	27898050	337659716**	201367888**	186605431**	84094054**	0.2350**	0.0719**
Tillage x Weed control method	3	0	0	1798950	4159939*	1798950	4159939*	0.0052	0.0135*
Seed rate x Weed control method	6	0	0	2134559	646588	2134559	646588	0.0079	0.0021
Tillage x Seed rate x Weed control method	6	0	0	1440241	142140	1440241	142140	0.0061	0.0005
Error (b)	36	0	0	2074853	1340818	2074853	1340818	0.0084	0.0045
Total	71	2119709	2487737	18849369	10960953	11597127	5443137	0.0452	0.0178

* Significant at 5 % level
** Significant at 1 % level

APPENDIX-XXVa
Prices of different input and output resources

Particular	Unit	Price (Rs.)	
		2002-03	2003-04
Wheat seed	1 kg	13.5	20
Urea	1 q	432	480
S.S.P.	1 q	300	304
Irrigation	1 hr	40	40
Isoproturon (50%)	1 kg	203	203
Gramaxone (24%)	1 litre	262	262
Tractor with implement	1 hr	200	200
Labourer	1 man day	58	58
Wheat grains	1 q	630	630
Wheat straw	1 q	180	180
Thresher	1 hr	200	200

APPENDIX-XXVb
Common cost of cultivation (Rs. ha^{-1})

Particular	Quantity required (ha^{-1})	Cost (Rs.)	
		2002-03	2003-04
SOWING			
Furrow opening	5.5 hrs	1100	1100
Roller	1.5 hrs	300	300
FERTILIZERS			
120 kg N ha^{-1} through Urea	260 kg	1127	1252
60 kg P ha^{-1} through S.S.P.	375 kg	1125	1140
IRRIGATION			
Pre-sowing	14 hrs	560	560
Post-sowing -1	18 hrs	720	720
2	14 hrs	----	560
3	14 hrs	560	560
THRESHING	8 hrs	1600	1600
LABUUR REQUIRED			
Lay out	4	232	232
Fertilizer application	4	232	232
Sowing	8	464	464
Irrigation	12/16	696	928
Bund and channel making	8	464	464
Harvesting	16	928	928
Threshing	6	348	348

APPENDIX-XXVc
Fixed cost of cultivation (Rs. ha^{-1})

Treatment	Cost (Rs.)	
	2002-03	**2003-04**
Tillage (with labour charges)		
Till	2400	2400
No-till	820	820
Seed rate (kg)		
100	1350	2000
150	2025	3000
200	2700	4000
Weed control method (with labour charges)		
Hand weeding	1450	1450
Isoproturon @1.0 kg a.i.	680	680
Weed-free	2900	2900
Weedy check	000	000

APPENDIX-XXVd

Treatment vise cost of cultivation (Rs. ha^{-1})

Treatment	Cost (Rs.)	
	2002-03	2003-04
T-100-HW	15656	17238
T-100-ISO	14886	16468
T-100-WF	17106	18688
T-100-W	14206	15788
T-150-HW	16331	18238
T-150-ISO	15561	17468
T-150-WF	17781	19688
T-150-W	14881	16788
T-200-HW	17006	19238
T-200-ISO	16236	18468
T-200-WF	18456	20688
T-200-W	15556	17788
NT-100-HW	14076	15658
NT-100-ISO	13306	14888
NT-100-WF	15526	17108
NT-100-W	12626	14208
NT-150-HW	14751	16658
NT-150-ISO	13981	15888
NT-150-WF	16201	18108
NT-150-W	13301	15208
NT-200-HW	15426	17658
NT-200-ISO	14656	16888
NT-200-WF	16876	19108
NT-200-W	13976	16208

Whereas,

T=Till

NT=No-till

100=100 kg seed rate

150=150 kg seed rate

200=200 kg seed rate

HW=Hand-weeding, 30 DAS

ISO=Isoproturon @1.0 kg a.i. ha^{-1}, 35DAS

WF=Weed-free

W=Weedy check

APPENDIX-XXVI

Interaction effect of tillage and weed control method on weed density at 30 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	6.17 (482)	6.20 (500)	0.00	6.18 (489)	6.08 (447)	6.08 (445)	0.00	6.08 (448)
No-till	5.69 (304)	5.67 (308)	0.00	5.70 (311)	5.66 (294)	5.59 (278)	0.00	5.65 (296)

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.09	0.09	0.25	0.26
For comparing two tillage at the same or different level of weed control method	0.08	0.09	0.25	0.25

Original values in parenthesis

APPENDIX-XXVII

Interaction effect of tillage and weed control method on weed density at 60 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	4.53 (97)	5.26 (195)	0.00	6.34 (567)	4.74 (120)	5.39 (221)	0.00	6.40 (605)
No-till	4.65 (112)	5.02 (156)	0.00	5.93 (379)	4.70 (115)	5.07 (161)	0.00	5.98 (397)

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.08	0.06	0.24	0.18
For comparing two tillage at the same or different level of weed control method	0.10	0.07	0.28	0.21

Original values in parenthesis

APPENDIX-XXVIII

Interaction effect of tillage and weed control method on weed density at 90 DAS during 2003-04

Treatment	**Weed control method**			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	4.22 (78)	4.96 (145)	0.00	5.84 (350)
No-till	4.55 (100)	4.74 (122)	0.00	5.76 (318)

	S.Em.±	CD (P=0.05)
For comparing two weed control method at the same level of tillage	0.09	0.27
For comparing two tillage at the same or different level of weed control method	0.11	0.34

Original values in parenthesis

APPENDIX-XXIX

Interaction effect of tillage and weed control method on weed density at 120 DAS during 2003-04

Treatment	**Weed control method**			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	2.77 (17)	3.38 (30)	0.00	4.37 (81)
No-till	3.35 (29)	3.88 (49)	0.00	4.86 (131)

	S.Em.±	CD (P=0.05)
For comparing two weed control method at the same level of tillage	0.08	0.24
For comparing two tillage at the same or different level of weed control method	0.09	0.26

Original values in parenthesis

APPENDIX-XXX

Interaction effect of seed rate and weed control method on weed density at 120 DAS during 2003-04

Treatment	**Weed control method**			
Seed rate	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
100	3.40 (31)	3.84 (47)	0.00	4.69 (115)
150	3.16 (25)	3.64 (40)	0.00	4.63 (107)
200	2.62 (15)	3.41 (32)	0.00	4.52 (96)

	S.Em.±	CD (P=0.05)
For comparing two weed control method at the same level of tillage	0.10	0.29
For comparing two tillage at the same or different level of weed control method	0.11	0.32

Original values in parenthesis

APPENDIX-XXXI

Interaction effect of tillage and weed control method on weed dry weight (g m^{-2}) at 60 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	2.61 (12.8)	3.36 (28.2)	0.00	4.94 (140.9)	2.87 (16.9)	3.52 (33.3)	0.00	4.99 (147.8)
No-till	2.94(18.1)	3.80 (44.4)	0.00	4.70 (109.7)	2.98 (19.0)	3.84 (46.3)	0.00	4.70 (110.4)

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.05	0.04	0.14	0.11
For comparing two tillage at the same or different level of weed control method	0.05	0.04	0.13	0.12

Original values in parenthesis

APPENDIX-XXXII

Interaction effect of tillage and weed control method on weed dry weight (g m^{-2}) at 90 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	3.57 (35.0)	4.12 (61.4)	0.00	5.10 (164.5)	3.34 (22.8)	4.04 (56.4)	0.00	5.07 (158.9)
No-till	3.81 (44.7)	4.42 (82.7)	0.00	5.29 (198.6)	3.69 (39.7)	4.38 (79.9)	0.00	5.27 (195.0)

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.03	0.04	.010	.012
For comparing two tillage at the same or different level of weed control method	0.04	0.04	0.11	0.11

Original values in parenthesis

APPENDIX-XXXIII

Interaction effect of tillage and weed control method on weed dry weight (g m^{-2}) at 120 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	2.69 (14.0)	3.52 (33.1)	0.00	4.41 (81.9)	1.70 (4.8)	2.76 (15.3)	0.00	3.95 (51.7)
No-till	3.70 (39.7)	4.53 (92.7)	0.00	5.37 (215.9)	3.07 (21.2)	4.02 (55.5)	0.00	5.09 (162.1)

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	.04	.06	0.12	0.18
For comparing two tillage at the same or different level of weed control method	.04	.06	0.12	0.18

Original values in parenthesis

APPENDIX-XXXIV

Interaction effect of tillage and weed control method on weed control efficiency (%) at 60 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	93.92	80.66	100.00	0.00	88.58	77.55	100.00	0.00
No-till	84.15	58.50	100.00	0.00	82.85	58.15	100.00	0.00

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	1.98	2.02	5.68	5.80
For comparing two tillage at the same or different level of weed control method	1.80	2.01	5.21	5.87

APPENDIX-XXXV

Interaction effect of tillage and weed control method on nitrogen removal (kg ha^{-1}) by weeds at 60 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	2.36	5.07	0.00	23.81	3.12	5.99	0.00	24.97
No-till	3.33	7.99	0.00	18.53	3.50	8.33	0.00	18.65

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.63	0.61	1.82	1.74
For comparing two tillage at the same or different level of weed control method	0.61	0.61	1.78	1.79

APPENDIX-XXXVI

Interaction effect of tillage and weed control method on phosphorus removal (kg ha^{-1}) by weeds 60 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	0.75	1.63	0.00	8.00	0.99	1.93	0.00	8.39
No-till	1.06	2.57	0.00	6.23	1.11	2.68	0.00	6.27

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.21	0.20	.061	0.58
For comparing two tillage at the same or different level of weed control method	.020	0.20	0.60	0.60

APPENDIX-XXXVII

Interaction effect of tillage and weed control method on potassium removal (kg ha^{-1}) by weeds at 60 DAS during both the years

Treatment combination	Weed control method							
	2002-03				2003-04			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	2.62	5.74	0.00	27.19	3.46	6.78	0.00	28.52
No-till	3.70	9.05	0.00	21.17	3.88	9.44	0.00	21.30

	S.Em.±		CD (P=0.05)	
	2002-03	2003-04	2002-03	2003-04
For comparing two weed control method at the same level of tillage	0.72	0.69	2.07	1.98
For comparing two tillage at the same or different level of weed control method	0.70	0.70	2.03	2.04

APPENDIX-XXXVIII

Interaction effect of tillage and weed control method on gross return (Rs. ha^{-1}) during 2003-04

Treatment	Weed control method			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	38085	37096	41098	34033
No-till	37912	35993	40807	31775

	S.Em.±	CD (P=0.05)
For comparing two weed control method at the same level of tillage	386	1107
For comparing two tillage at the same or different level of weed control method	428	1263

APPENDIX-XXXIX

Interaction effect of tillage and weed control method on net return (Rs. ha^{-1}) during 2003-04

Treatment	Weed control method			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	19847	19628	21410	17245
No-till	21254	20105	22699	16567

	S.Em.±	CD (P=0.05)
For comparing two weed control method at the same level of tillage	386	1107
For comparing two tillage at the same or different level of weed control method	428	1263

APPENDIX-XXXX

Interaction effect of tillage and weed control method on net return $rupee^{-1}$ invested during 2003-04

Treatment	Weed control method			
Tillage	Hand weeding , 30DAS	Isoproturon @1.0 kg a.i.ha^{-1}, 35DAS	Weed-free	Weedy check
Till	1.09	1.13	1.09	1.03
No-till	1.28	1.27	1.26	1.09

	S.Em.±	CD (P=0.05)
For comparing two weed control method at the same level of tillage	0.02	0.06
For comparing two tillage at the same or different level of weed control method	0.02	0.07

VITA

The author of this manuscript was born on June 14th, 1976 in a farmer family at Chehadi village, District Saharanpur (U.P.). The author, has completed his Primary Education at Village level. He passed his High School from Janta Inter College Ambehata Chand, Saharanpur in 1991 and Intermediate from Gochar Krishi Inter College, Rampur Maniharan, Saharanpur in 1993. Subsequently, he joined Gochar Mahavidhalya, Rampur Maniharan, Saharanpur under C.C.S. University, Meerut for the degree of B.Sc. (Ag.) and obtained the same in the year 1997 with 66.7 percent. Thereafter, he joined R.M.P.P.V. College, Narsan, Hardwar under C.C.S. University Meerut in 1997 for M.Sc. (Ag.) Agronomy and completed in the year 1999 with 71.9 per cent. He then, got the opportunity to join G.B.P.U.A.&T., Pantnagar in September 2001 for Ph.D. programme. He persued the degree with major in Agronomy and minor in Soil Science under the kind supervision of Dr. R.C. Gautam, Professor (Agronomy). Author was also the recipient of University Scholarship during the Ph.D. programme.

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ABSTRACT

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Name of Advisor : Dr. R.C. Gautam

A field experiment was conducted during 2002-03 and 2003-04 at Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (29°N latitude, 79.29°E longitude and 243.8 m altitude) to study the effect of seed rate and weed control method on growth and productivity of wheat (*Triticum aestivum* L.) under till and no-till condition. Twenty four treatment combinations comprised of two tillage (i.e. till and no-till), three seed rate (i.e. 100, 150 and 200 kg ha^{-1}) and four weed control method (i.e. hand weeding 30 DAS, Isoproturon @ 1.0 kg ai ha^{-1} 35 DAS, weed free and weedy check) were tested in split-plot design with three replications keeping tillage and seed rate combination as main plot and weed control method as sub-plot.

Though maximum grain yield was obtained with weed free followed by hand weeding at 150 kg ha^{-1} seed rate under till (conventional) but no-till at 200 kg ha^{-1} seed rate also produced comparable grain yield. Differences in grain yield were not significant but till sowing gave 5.74 and 5.45 per cent higher grain yield as compared to no-till sowing during 2002-03 and 2003-04, respectively. Similar grain yield was noted with higher seed rate (150 and 200 kg ha^{-1}) as compared with 100 kg seed rate during both the years. Unchecked weeds caused nearly 26.47 and 27.28 per cent loss in grain yield. Significantly higher grain yield was recorded in weed free followed by hand weeding and isoproturon treatments as compared to weedy check during both the years.

Significantly higher number of spikes was recorded in till sowing at 200 kg seed rate which was very close to 150 kg with weed free treatment. Improvement in yield attributes (spike length, fertile spikelets, number of grains $spike^{-1}$, grain weight $spike^{-1}$ and 1000-grain weight) was observed in no-till sowing and at 100 kg seed rate. Improved yield attributes were also recorded under weed free treatment followed by hand weeding and isoproturon. All the weed control treatments as compared to weedy check resulted significant reduction in weed density, weed dry weight and crop-weed competition index. Hand weeding was significantly superior over isoproturon treatment.

No-till resulted lower cost of production, and it was 1.10 times more economical over the till sowing. Isoproturon at 1.0 kg ai ha^{-1} at 100 to 150 kg ha^{-1} seed rate under no-till treatment was found economically better.

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