The present investigation entitle "Integrated weed management in wheat (Triticum aestivum L. emend fiori and Poal)" can be revised under following headings.

2.1 WEED FLORA IN INDIA

In a country like India where agriculture predominates, weeds play a key role in its economy because these compete with crops for different growth factors such as nutrients, moisture, light and space, thus bringing about significant reduction in yield as well as in quality in wheat. For successful implementation of any weed control method, it is essential to have an adequate knowledge of weed flora of a particular area. Wheat is grown under varying edaphic and climatic situations in India, therefore, the occurrence of weed species and the nature of weed problems varies greatly.

NORTH INDIA

UTTAR PRADESH

Survey of weed flora of wheat grown in eastern part of Uttar Pradesh has been conducted by the weed scientists of NDUAT, Kumarganj, Faizabad during different years. It has been observed during the course of study that wheat crop was seen to be severely infested by divergent weed flora like Anagallis arvensis, Convolvulus arvensis and Melilotus alba. Anagallis arvensis, Chenopodium album,
Melilotus indica, Spergula arvensis, Lathyrus aphaca, Vicia hirsuta, V. sativa, Euphorbia dracunculoides, Desmodium triflorum, Launaea asplenifolia, Cirsium arvense, Asphodelus tenuifolius and Convolvulus arvensis among dicot weeds, Phalaris minor, Avena fatua and Cynodon dactylon among monocot weeds and Cyperus rotundus among sedges (Vaishya and Khan, 1986 and Vaishya et al., 1988) and late sown wheat crop was seen to be infested by eight weed species namely Phalaris minor, Cynodon dactylon, Chenopodium album, Polygonum plebejum, Vicia sativa, Anagallis arvensis, Melilotus indica and Cyperus rotundus (Shripakash, 1986) and Vicia hirsuta, Cyperus rotundus, arvensis, Asphodelus tenuifolius Phalaris minor, Chenopodium album, Fumaria parviflora, Melilotus indica and Launaea asplenifolia (Tripathi and Vaishya 1997) and Phalaris minor, Cynodon dactylon, Cyperus rotundus, Anagallis arvensis, Chenopodium album, Polygonum plebejum, Vicia hirsute and Spergula arvensis (Yadav, 1999) and Chenopodium album, Melilotus indica, Anagallis arvensis, Phalaris minor, Cyperus rotundus and Convolvulus arvensis (Bikramaditya et al., 2000) and at CRS, Ghagrakhe (NDUAT, Faizabad) it has been observed by Singh and Singh (1996) that late sown wheat crop was infested by Phalaris minor, Avena fatua, Fumaria parviflora, Chenopodium album, Anagallis arvensis, Convolvulus arvensis and Melilotus alba. At Banaras Hindu university, Varanasi, it has been observed by Singh et al. (1977a) that wheat crop was heavily infested by Melilotus spp. Chenopodium album, Phalaris minor, Anagallis arvensis, Cyperus rotundus and Cynodon dactylon, Sinha et al. (1999)
observed at same place that *Anagallis arvensis, Chenopodium album, Melilotus alba, Spergula arvensis, Phalaris minor, Cyperus rotundus* and *Cynodon dactylon* were the major dominant weed species in wheat crop. At J.V. College, Baraut, Meerut (U.P.) It has been observed by Chopra et al. (1999) that wheat crop was dominated with *Phalaris minor, Fumaria parviflora, Chenopodium album, Anagallis arvensis, Cirsium arvense and Rumex dentatus*.

**UTTRANCHAL**

At GBPUAT, Pantnagar, it has been observed by Singh (1996) that the field of wheat was seen to be infested with *phalaris minor, Avena ludoviciana, Chenopodium album, Melilotus spp., Rumex acetosella, Anagallis arvensis, Vicia sativa, Lathyrus aphaca, Fumaria parviflora, Medicago denticulata, Spergula arvensis, Cyperus, rotundus and cynodon dactylon*. Prasad et al. (1999) reported from the same place that the major weeds were *phalaris minor, Chenopoldium album, Melilotus spp. and Anagallis arvensis* in wheat crop. The weed flora of wheat crop grown at VPKAS, Almora included *Phalaris mionor, Avena ludoviciana, Stellaria media, Anagallis arvensis and Pholygonium piebejum* (Pandey et al. 1998).

**PUNJAB**

Gill and Brar (1975) and Jain et al. (1985) reported from PAU, Ludhina that the wheat crop was infested by several weed species namely *Phalaris minor, Avena spp; Spergula arvensis, Poa annua, Setaria spp; Anagallis arvensis, Vicia spp. and Cyperus rotundus.*
HARYANA

The weed flora grown under normal as well as late sown conditions in Haryana state have been indicated in this paragraph. Several weed scientists working at CCSHAU, Hissar reported that the wheat crop was found to be infested with Phalaris minor, Avena ludoviciana, Anagallis arvensis, Melilotus indica, Chenopodium album, Rumex maritimus, Cirsium arvense weeds predominantly (Khatu et al. 1997; Singh et al. 1987; Singh et al. 1997C; Panwar et al. 1999 and Sharma and Pahuja, 2001).

HIMACHAL PRADESH-

At Regional Research Station, Bajaura (HPKV, Palampur), it has been observed by Sharma and Sharma (1997) and Thakur and Singh (1999) that the wheat crop was mainly infested by Phalaris minor, Poa annua, Lolium tenulentum, Avena ludoviciana, Veronica persica, Capsella bursapestoris, Medicago denticulata and Anagallis arvensis. Sharma (1995) working at RRS, Kukumseri (HPKV), reported that the major weed flora present in the wheat crop were Phalaris minor, Lolium tenulentum, Poa annua among grasses and Anagallis arvensis, medicagos denticulata and Capsella bursapestoris among dicot weeds.

EAST INDIA

BIHAR

Prasad et al. (1999) working at RAU, Pusa that the weed flora of wheat crop was seen to be infested mainly by Chenopodium album, Fumaria parviflora, Melilotus indica, Convolvulus arvensis, Trigonella
polycerate, Oxalis corniculata, Spergula arvensis, Lipia nodiflora, Nicotiana plumbaginifolia, Phalaris minor, Avena fatua, Cynodon dactylon and Cyperus rotundus. Pandey et al. (2001) has also been reported from the same place that weed flora of wheat crop included Chenopodium album, Anagallis arvensis, Fumaria parviflora, Convolvulus arvensis, Vicia sativa, Launaea pinnatifida, Asphodelus tenuifolius, Phalaris, minor, Avena fatua, Cynodon dactylon and Cyperus rotundus were the major weed species infesting the wheat crop.

ORISSA

The scientists working at OUAT, Bhubaneswar observed that wheat crop under this agroclimatic condition was badly infested by 20 weed species namely Cynodon dactylon, Doctyloctenium aegypticum, Digitaria ciliaris, Echinochloa colonum, Eleusine indica, Pasalam scrobiculatum, Cyperus rotundus, Fimbristylis milacea, Ageratum conyzoides, Cleome viscosa, Commelina benghalensis, Croton sparsiflora, Physalis minima and phylanthus niruri (Panda et al. 1996) Grasses were the dominant weeds followed by non-grasses and sedges, Leptochloa chinensis, Echinochloa colonum Cynodon dactylon and Digitaria sanguinalis among the grassy weeds and Chenopodium album, Eclipta alba, Amaranthus viridis and Blumea lacera among the broad leaved weeds while Cyperus rotundus was the only sedge with infestation.
WEST BENGAL

Chaubey *et al.* (1998) reported from IIT, Kharagpur that the predominant weed species found in wheat crop included *Enhydra fluctuans*, *Physalis minima*, *Solanum nigrum*, *Chenopodium album*, *Heliotropicum indicum*, *Digitaria sanguinalis*, *Echinochloa colonum*, *Cynodon dactylon* and *Eleusine indica*.

WEST INDIA

CHATTISGARH

Dwivedi *et al.* (1996) reported from IGKV, Zonal Agril. Research station, Ambikapur that the pre-dominant weed species recorded in the wheat were *Phalaris minor*, *Chenopodium album*, *Anagallis arvensis*, *Cynodon dactylon*, *Avena fatua* and *Vicia sativa*.

MADHYA PRADESH

Survey of weed flora in wheat crop areas has been conducted by a number of scientists working in different institutions under various agro-climatic zones of M.P. and the results are reviewed in this paragraph. The scientists working at NRC for weed science Jabalpur observed that the field of wheat was infested mainly by *phalaris minor*, *Chenopodium album*, *Cyperus rotundus*, *Chichorium intybus*, *Medicago dentoculata*, *Rumex dentata* and *Trifolium flagiferum* (Dixit and Bhan, 1997; Singh and Bhan, 1997, Singh *et al.* 1997b; Dixit and Bhan 1999), *Jain et al.* (1990) working at JNKVV, Jabalpur observed that the wheat field was found to be infested with divergent weed flora namely *Phalaris minor*, *Trifolium flagiferum*, *Medicago denticulata*, *Melilotus alba* and *Chenopodium album*. Sharma (1991) reported from
College of Agriculture, Gwalior that the dominant weeds namely *Phalaris minor*, *Chenopodium album*, *Avena ludoviciana*, *Anagallis arvensis*, *Melilotus indica*, *Vicia sativa* and *Trianthema monogyna* were heavily infested with wheat crop.

**MAHARASTRA**

At Prabhani, it has been observed by Shalunke *et al.* (1990) that dominant grasses infesting wheat crop were *Brachiaria cruciformis* and *Cynodon dactylon* while prominent broadleaves weeds were *Convolvulus arvensis*, *Sanchrus arvensis*, *Euphorbia dracunculoides*, *Achyranthus aspera*, *Amaranthus spinosus* and *Argemone maxicana*.

**DELHI**

Yaduraju and Ahuja (1997) reported form IARI; New Delhi that in the field of wheat the major weeds were *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album* and *Melilotus incica*.

**2.2 LOSSES CAUSED BY WEEDS**

Weeds are the most damaging pests and cause severe crop losses however, the degree of severity differ considerably depending upon methods of wheat cultivation. Weeds cause two types of crop losses, the most important is the direct yield loss resulting from competition for different growth factors followed by indirect loss from reduced crop quality, (De-Datta, 1980).

Significant yield losses due to weed infestation in wheat grown in Uttar Pradesh have been observed by a number of scientists. The results of the field experiments conducted at Agronomy Research Farm of NDUAT, Faizabad showed that infestation of weeds in wheat
reduced the crop yield by 25 per cent (Vaishya and Khan, 1988) and 19.68 per cent (Bikramaditya et al., 2000) When compared with weed free check. Singh and Singh (1996) from CRS, Ghagrahat (NDUAT, Faizabad) that the invasion of weeds reduced the yield of late Sown Wheat by 10.28 to 73.68 per cent, also reported that weed infestation is more in broad casting wheat followed by line sowing and least in cross sowing wheat. Consequently, the extent of losses in wheat yield also depends upon method of sowing adopted for wheat cultivation.

Pandey et al. (1998) working at VPKAS, Almora, reported that yield losses in wheat due to unchecked weed growth was 28.9 to 52.2 per cent when compared with weed free check while Singh (1996) reported from GBPUAT, Pantnagar that the yield losses in wheat due to unchecked weed growth was 40.2 per cent.

Gautam et al. (1974) recorded that heavy reduction in wheat yield due to serious weed competition at IARI, New Delhi.

Losses in grain yield due to weeds is a function of weed flora and duration of weed infestation but 15-50 per cent reduction in timely sown wheat is quite usual reported by Gill and Brar (1975) from PAU, Ludhina. Gill and Brar (1977) also reported that 15-30 per cent reduction in grain yield of late sown wheat due to severe weed competition.

Reduction in yield of wheat due to weeds to the tune of 33.14 per cent has been reported by Pandey et al. (1997) from RAU, Pusa (Bihar).
2.3 CRITICAL CROP-WEED COMPETITION

Weeds growing in association with crop plants compete with both rhizosphere and biosphere. Weed competition depends upon weed species, density of crop and weed, soil moisture, nutrients availability and period of competition. Weeds must be controlled within the critical period of weed crop competition. Most of the time control measures are adopted when the losses have already taken place. The timeliness of weed control operations is an important as control itself. The period during which weeds can be tolerated by the crop without reduction in the final yield depends not only on the characteristics of weed and crop but also on the period for which weeds are associated with the crop. Parameters like crown root initiation, number of ear heads per unit length and number of grains ear\(^{-1}\) head and test weight are adversely affected in the absence of adequate weed control. Establishing the critical period of competition is essential to develop effective and economical weed control measures (Sharma \textit{et al.} 1977).

The reductions in grain yield owing to weed competitions for initial 15, 30, 45 and 60 days were 3.5, 7.8, 14.5 and 21 per cent, respectively as compared with season long weed free treatment. Increasing the weed-free condition up to 45 or 60 days after sowing resulted in crop yield comparable to season long weed free. Thus, the most critical period of competition between crop and weeds lies between 30 and 45 days after sowing (Gogoi \textit{et al.}, 1993). When weeds are allowed to compete with the crop for initial period of 15, 30, 45 and
60 days and removed thereafter caused 6.28, 8.09, 20.93 and 24.96% reduction in grain yield of wheat, respectively to WF conditions and when weeds were removed up to first 40-45 days of crop growth then no significant reduction in yield was evident. Therefore, the critical period of weed crop competition was worked out to be the first 33 to 40 DAS in wheat (Chopra et al. 1999)

2.4 EFFECT OF METHOD OF SOWING

2.4.1 Effect on weeds

Methods of sowing comes under cultural method of weed control. Method of sowing may boost the competition abilities of crops and may also substitute for chemical weed control. Minimum weed dry weight was observed with double line sowing and maximum under broadcast sowing (Singh et al. 1987). Maurya (1991) reported from NDUAT, Faizabad that cross sowing method significantly reduced the weed population and weed dry weight per unit area over unidirectional and broadcast sowing method. He also reported that broadcast sowing method encouraged the weeds to take up significantly more nitrogen than normal row and cross sowing methods. Tomar et al. (1999) reported from the same place that weed density and weed dry weight were minimum in closer row spacing followed by cross sowing. Nanda and Patro (1996) observed from OUAT, Orissa that close spacing of 15 cm recorded lesser dry weight of weeds which could be due to higher plant density to that of lower one at wider row spacing. Yadav et al. (2005) reported that the
significant reduction in dry weight of weeds was observed with cross sowing over conventional method.

2.4.2 Effect on uptake of nitrogen by weeds

Nutrients removed by weed species is the function of weed biomass and their respective contents. Grass weeds have potential to remove 40 to 50 kg N ha\(^{-1}\) in wheat (Walia and Gill, 1985). Johri et al. (1992) reported from GBPUAT, Pantnagar that cross sowing of wheat in response to one direction sowing resulted into reduction of nutrients uptake of weed species. In total, there was 13,11and 16\% reduction in N, P\(_2\)O\(_5\) and K\(_2\)O uptake by all weed species, respectively.

2.4.3 Effect of crops

2.4.3.1 Effect on growth characters

It has been reported by Maurya (1991) from NDUAT, Faizabad that cross and normal sowing methods in wheat crop registered significantly more number of initial plant population than broadcast sowing method. He further reported that significantly maximum shoot height, number of tillers and functional leaves were recorded by cross sowing method as compared to normal row and broadcast sowing methods. Singh et al. (1987) reported from RAU, Pusa (Bihar) that paired row sowing had slightly higher effective tillers over broadcast, normal line sowing and criss-cross sowing but all the methods were statistically at par. He further observed that criss-cross sowing of wheat recorded significantly higher LAI (g/m\(^2\) /day) at 30\(^{th}\), 60\(^{th}\) and 90\(^{th}\) day stages of crop as compared to broadcast, normal line sowing
and double line sowing while all the sowing methods did not exert significant on total dry matter production.

2.4.3.2 Effect on yield contributing characters

The results of a field experiment conducted by Maurya (1991) at NDUAT, Faizabad revealed that cross sowing method of wheat gave significantly more number of spikes m⁻², higher number of spikelets, grain ear⁻¹ and 1000 grains weight than broadcast and line sowing method. The ear length and grains weight ear⁻¹ recorded by unidirectional and cross sowing methods were similar but were significantly greater than broadcast sowing method. The scientists of CRS, Ghagrachat (NDUAT, Faizabad ) reported that cross sowing of wheat registered significantly longer spike and more number of grains ear⁻¹ than normal, closer and broadcast sowing methods (Singh et al., 1993 and Singh and Singh, 1996) .

2.4.3.3 Effect on grain and straw yields

Singh et al. (1987) reported from RAU, (Bihar) that all the methods of sowing viz., broadcast, normal line sowing , double line sowing and criss cross sowing though did not differed amongst themselves but were significantly superior to broadcast sowing in recording grain yield.

Maurya (1991) reported from NDUAT, Faizabad that the cross sowing method was found most favourable to record significantly higher grain and straw yields than normal row and broadcast sowing method in wheat. Tomar et al. (1999) working at same place, reported that closer row spacing and criss cross sowing methods produced
significantly the highest grain and straw yields compared with unidirectional sowing method.

The results of work done at MPKV Akola in Maharashtra in respect of method of sowing to the weed control in wheat by Jodhao and Nalamwar (1993), indicated that cross sowing at 22.5 cm had significantly higher grain and straw yields than those of normal, closer and cross sowing at 15 cm sowing methods. Yadav et al. (2005) revealed that grain yield and number of effective tillers m\(^{-1}\) row increased significantly by 7.7 and 6.0 %, respectively with cross sowing over broadcasting.

2.5 EFFECT OF SEED RATE

2.5.1 Effect on weeds

Seed rate, a cultural method of weed control, also affects the weeds. Increased seed rates significantly reduced the weed population and dry weight of seeds. The lower weed population and dry weight recorded under higher seed rates of crop might be due to the competition offered by the crop plants space, nutrients, moisture and solar radiation. In Haryana, it has been reported by Panwar et al. (1989) from CCSHAU, Hissar that there was greater decrease in weed dry weight at 150 kg seed ha\(^{-1}\).

At IARI, Pusa (New Delhi) it has been observed by Yaduraju and Ahuja (1997) that higher seed rate (150kg ha\(^{-1}\)) significantly reduced the *Phalaris minor* dry weight and also total weed biomass over recommended rate of 100 kg ha\(^{-1}\).
Singh and Verma (2000) reported from RRS, Madhopur (RAU, Bihar) that higher seed rate of wheat to the tune of 175 kg ha\(^{-1}\) was found effective in reducing the dry matter of weeds.

Prasad *et al.* (2005) found that application of herbicides significantly reduced the population and dry matter production of weeds over no application. Less weed population and weed dry matter were recorded with isoproturon + 2, 4-D than sulphosulfuron.

### 2.5.2 Effect on crop

#### 2.5.2.1 Effect on growth characters

An optimum and uniform plant population is a pre-requisite for obtaining maximum potential of wheat crop. The results of an experiment conducted by Panwar *et al.* (1989) at CCSHAU, Hissar revealed that higher seed rate of 150 kg ha\(^{-1}\) recorded taller plants over 100 kg ha\(^{-1}\). Mahajan *et al.* (1991) reported from Rewa (M.P.) that higher seed rate of 150 kg ha\(^{-1}\) significantly increased the plant height and decreased effective tillers plant\(^{-1}\) over 100 kg ha\(^{-1}\).

The research findings of an experiment conducted by Sriprakash (1996) at NDUAT, Kumarganj, Faizabad indicated that initial plant population, plant height and functional leaves plant\(^{-1}\) were not influenced appreciably by varying seed rates at all the stages. But, the number of tillers plant\(^{-1}\) was better at 75\(^{th}\) day stage under use of 125 kg seed rate ha\(^{-1}\). Yadav (1999) also reported from the same place that the use of 125, 150 and 175 kg seed rate ha\(^{-1}\) did not show their significant effects on plant height, number of tillers and functional leaves plant\(^{-1}\) almost at all the stages of crop growth.
Pandey and Kumar (2005) reported that all leaf area index were maximum under hand weeding which was at par with sulphosulfuron @ 33.30 g ha\(^{-1}\) significantly higher than isoproturon + 2, 4-D.

**2.5.2.2 Effect on yield contributing characters**

Narang and Sachan (1971) described that the conditions prevalent at the time of “Ear development and grain formation” play more significant role than other ones prevailing at earlier phases of life cycle of the plant.

Pawar *et al.* (1987) observed at MPAU, Maharashtra, the plants in the treatment with 75% of the recommended seed rate (90 kg ha\(^{-1}\) produced significantly longer panicles. However, differences in respect of 1000-grain weight and number of grains panicles\(^{-1}\) were not significant.

Sriprakash (1996) reported from NDUAT, Faizabad that different yield attributing characters viz., number of spikes m\(^{-2}\), length of spike, number of spikelets, grains ear\(^{-1}\) and 1000-grains weight were not influenced by varying seed rates.

Pandey and Kumar (2005) reported that all yield indices such as tillers m\(^{-2}\), ear length and grains ear\(^{-1}\) were maximum under hand weeding which was at par with sulfo-sulfuron @ 33.30 g ha\(^{-1}\) but significantly higher than isoproturon @ 0.75 kg ha\(^{-1}\) + 2, 4-D.

Pandey *et al.* (2005) reported that the isoproturon was equally effective hand weeding and isoproturon + 2, 4-D in respect of tillers m\(^{-2}\), ear length and grains ear\(^{-1}\).
Prasad et al. (2005) reported that the application of isoproturon + 2, 4-D produced significantly higher number of ear heads m\(^{-2}\).

### 2.5.2.3 Effect on grain straw yields

Shukla (1987) observed from NDUAT, Faizabad that the use of 150 kg seed ha\(^{-1}\) was found most appropriate as compared to 125 and 175 kg seed rates to recur significantly more grain and straw yields while Sriprakash (1996) reported that varying seed rates i.e. 125 and 150 kg ha\(^{-1}\) did not cause significant variations in recording the grain and straw yield.

Singh et al. (1996) reported from CCSHAU, Hissar that under weedy check and chemical control treatments highest grain yield of wheat was recorded with 150 kg ha\(^{-1}\) seed rate, which might be due to reduced weed competition and increased the number of ears m\(^{-2}\).

Singh et al. (1999) observed at RAU, Pusa(Bihar) that use of 200 kg seed ha\(^{-1}\) produced significantly grain yield than 100 and 150 kg seed rates ha\(^{-1}\).

### 2.6 EFFECT OF WEED MANAGEMENT PRACTICES

Herbicides are chemicals capable of killing or inhibiting the growth of plants. At present every type of weed problem can be solved with herbicides. In several instances, they offer the most practical, effective and economic means for controlling weeds. In addition, they offer sociological benefits like reducing number of labourers to work in farming etc. The research works done in past on the herbicides with an object to control the weeds and enhance the yield of wheat are being reviewed as under.
2.6.1 Effect on weeds

Field experiments on weed control in wheat with herbicides have been conducted by a number of scientists in different agro-climatic zones of Uttar Pradesh and the results obtained are being reviewed in this paragraph. Maurya (1991) reported from NDUAT, Kumarganj, Faizabad that application of isoproturon @ 1.0 kg ha\(^{-1}\) and supplement with one H.W. 40 DAS produced significantly the lowest weed density and weed dry weight than H.W. 20 and 40 DAS alone and isoproturon @ 1.0 kg ha\(^{-1}\) as post-em. Took up lesser nitrogen from the soil.

Tomar et al. (1999) reported from the same place that pre-em. application of pendimethalin @ 1.0 kg ha\(^{-1}\) with one hand -weeding at 35 DAS was at par with two H.W. at 20 and 45 DAS in reducing the weed dry weight and nutrients uptake over pendimethalin @1.0 kg ha\(^{-1}\) pre-em; 2, 4-D @1.0 kg ha\(^{-1}\) at 35 DAS and 2,4-D @ 1.0 kg ha\(^{-1}\) at 35 DAS in combination with one hand weeding at 20 DAS.

Singh (1996) reported from GBPUART, Panthnagar that at 60\(^{th}\) day stage weed dry weight was significantly lower in pendimethalin @1.5 kg ha\(^{-1}\) and twice hand weeding over weedy.

Dwivedi et al. (1996) working at IGKVZARS, Ambikapur, Chattisgarh observed that application of isoproturon either alone or in combination with 2, 4-D produced minimum weed dry weight as compared to other treatments. Combined application of isoproturon + 2, 4-D suppressed the weed growth effectively and recorded minimum weed dry weight.
Dixit and Bhan (2001) reported from NRC for weed science, Jabalpur (M.P.) that increasing doses of isoproturon up to 1.5 kg ha\(^{-1}\) significantly decreased the total weed density as well weed dry weight. combination of isoproturon @ 1.0 kg ha\(^{-1}\) + 2, 4 - D @ 0.5 kg ha\(^{-1}\) proved most effective as they controlled all weed species present in the field of wheat.

Sharma and Pahuja (2001) working at CCSHAU, Hissar observed that maximum reduction in weed density was recorded in Metribuzin @ 200 and 400 g ha\(^{-1}\) treated plots which was followed by chlorsulfuron @ 30 g ha\(^{-1}\) and metsulfuron methyl @ 8 g ha\(^{-1}\) treated plots. They also reported that minimum nutrient depletion by weeds was recorded under metribuzin treated and hand weeded plots expressed with the highest reduction in total weed density under these treatments.

Pandey et al. (2001) conducted an experiment at RAU, Bihar and observed that mixture of 2, 4 -D and isoproturon (0.4 kg ha\(^{-1}\) + 0.4 kg ha\(^{-1}\) ) recorded significantly lower weed population and weed dry biomass than 2,4-D @ 0.8 kg ha\(^{-1}\) alone. They also reported minimum removal of nutrients by weeds was registered in hand weeded plot which was significantly lower than herbicidal treatments.

2.6.2 Effect on crop

2.6.2.1 Effect on growth characters

At NDUAT, Faizabad it has been observed by Maurya (1991) that all the weed control treatments were found most promising to record more shoot height, number of tillers functional leaves plant\(^{-1}\) at
almost all the stages of crop growth as compared to weedy check, but initial plant population per unit area was not influenced by different weed management practices.

Singh et al. (1987) working at RAU, Pusa (Bihar) reported that among weed control practices maximum LAI was recorded at 60 and 90 DAS with isoproturon @ 1.0 kg ha\(^{-1}\) and methabenzthiazuron @ 1.5 kg ha\(^{-1}\) while maximum dry matter accumulation by plant was recorded with methabenzthiazuron @1.5 kg ha\(^{-1}\) which was found significantly superior to weedy check. Pandey et al. (2000) also reported from the same place that all the weed control treatments recorded significantly higher values of plant height and effective tillers than weedy check.

At NRC for weed science, Jabalpur (M.P.) it has been observed by Dixit and Bhan (2001) that post-emergence application of isoproturon +2, 4 –D (0.75 kg ha\(^{-1}\) + 0.5 kg ha\(^{-1}\) or 1.0 kg ha\(^{-1}\) + 0.5 kg ha\(^{-1}\)) produced statistically similar number of effective tillers per meter row length to that obtained under weed free plots.

### 2.6.2.2 Effect on yield contributing characters

The superiority of weed management practices over weedy treatment has also been reported by Singh et al. (1987) from IARI, New Delhi to record significantly more 1000-grain weight.

The result of field experiments conducted at HPKV, Palampur by the different scientists have been reviewed in this paragraph. Thakur and Singh (1998) reported that under late sown condition isoproturon @ 1.25 kg ha\(^{-1}\) post-em. and H.W. twice gave better
response on yield attributes viz, number of spikelets and grains spike\(^{-1}\), weight of grains spike\(^{-1}\) and test weight which were significantly greater than weedy treatment. Angiras and Sharma (1993) observed that different weed management practices shown their superiority over weedy check treatment in respect of producing more number of effective tillers m\(^{-2}\), spike length, number of spikelets and grains spike\(^{-1}\) and 1000 grain weight.

A field experiment have been conducted to find out the effect of weed management practices on wheat by various scientists working at NDUAT, Faizabad and the results are being summarized in following lines. Maurya (1991) reported that post emergence isoproturon 1.0 kg ha\(^{-1}\) + H.W. 40 DAS proved its superiority over rest of the weed management practices in recording more ear length, number of spikelets and grains spike\(^{-1}\) and 1000 grain weight. Yadav (1999) observed that pre-emergence application of isoproturon 1.0 kg ha\(^{-1}\) was better than unweeded check treatment in respect of registering higher values of number of spikelets and grains spike\(^{-1}\), weight of grains spike\(^{-1}\) and test weight.

### 2.6.2.3 Effect on grain and straw yield

The results of field experiments conducted at NDUAT, Faizabad by the different scientists have been reviewed in this paragraph. Maurya (1991) reported that hand weeding twice done at 20 and 40 DAS being at par with isoproturon applied @1.0 kg ha\(^{-1}\) post-em. + HW 40 DAS registered significantly higher grain and straw yields than the application of isoproturon alone and unweeded check.
Bikramaditya (2000) observed that weed free treatment registered the highest grain yield of wheat which was at par with the post-em. application of 2, 4-D Na salt @ 0.5 kg ha\(^{-1}\) and was significantly higher than rest of the weed control measures. The per-em application of pendimethalin @ 1.0 kg ha\(^{-1}\) with one hand weeding at 35 DAS was at par with two hand weeding at 20 and 45 DAS for enhanced crop yield and nutrients uptake over rest of the weed management practices (Tomar et. al, 2000).

Dwivedi et al. (1996) reported from IGKVZARS, Ambikapur, Chattisgarh that tank mix application of isoproturon and 2,4-D Na salt each @ 0.75 kg ha\(^{-1}\) provided significantly higher grain yield of wheat than their separate use.

The results of field experiments conducted by a number of scientist working at RAU, Pusa, Bihar have been reviewed in this paragraph. Thakur et al. (1998) reported that among the weed control treatments, hand weeding recorded significantly higher grain and straw yields than mixture of lower dose of 2,4-D and isoproturon (0.2 + 0.2 kg ha\(^{-1}\)) and weedy check, but was found to be at par with other control treatments. Pandey et al. (1998) observed that weed control treatments resulted in significantly higher grain and straw yield than weedy check. Highest grain and straw yields were recorded in hand weeding which was significantly higher than isoproturon @ 0.75 kg ha\(^{-1}\) and 2, 4-D @ 0.8 kg ha\(^{-1}\) but was at
par with mixture of isoproturon and 2, 4-D (0.4 + 0.4 kg ha⁻¹) as reported by Pandey et al. (2001).

Singh (1996) reported from GBPUAT, Pantnagar that pre-em. application of pendimethalin @ 1.5 kg ha⁻¹ being at par with hand weeding twice done at 35 and 45 DAS, post-em application of isoproturon @ 1.5 kg ha⁻¹ resulted significantly higher grain yield than all the remaining weed control measures and weedy check.

2.7 EFFECT OF INTERACTIONS

2.7.1. Effect of method of sowing x seed rate

Kolhe and Tripathi (2000) reported from IGAU, Raipur that cross sowing of wheat was found beneficial over normal sowing with higher seed rate increasing grain yield of wheat.

Singh and Verma (1999) reported from RRS (RAU, Bihar) that the treatment combination of 175 kg ha⁻¹ seed rate along with cross sowing of wheat produced the maximum grain yield being at par with 2, 4-D Na salt and 2, 4-D in all three years of experimentation.

Singh et al. (1993) reported from CRS, Ghagrahat (NDUAT, Faizabad) that the highest grain yield was obtained with the combination of cross sowing method and 125 kg seed⁻¹.

2.7.2 Effect of method of sowing x weed management practices

Maurya (1991) reported that the cross sowing method in combination with HW 20 and 40 DAS being significantly equal to combination of cross sowing method + isoproturon applied @ 1.0 kg ha⁻¹ post-em and supplemented one hand weeding at 40 DAS was found most promising to record significantly lower density and weed
dry weight and higher grain and straw yields than the remaining combinations of both the factors. Singh and Singh (1996) reported from CRS, Ghagraghat (NDUAT, Faizabad) that tank mix spray of isoproturon and 2, 4-D Na salt (0.75 + 0.5 kg ha\(^{-1}\)) in cross sown wheat resulted significantly reduced weed density, weed dry weight and higher grain yield over the other combinations of both the factors under late sown condition, Yadav (1999) also reported from the same place that the combined effect of cross and unidirectional methods of sowing in combination with pre-em pendimethalin 1.0 kg ha\(^{-1}\) or post em isoproturon @ 1.0 kg ha\(^{-1}\) was found most effective to reduce the weed density per unit area at 60\(^{th}\) day stage of crop growth and recorded higher grain yield and nitrogen Uptake by crop.

**2.7.3 Effect of seed rate and weed management practices**

The results of trial conducted by Panwar et al. (1989) at CCSHAU, Hissar revealed that the effect of isoproturon was more at higher seed rates compared with 100 kg seed ha\(^{-1}\) in respect of reducing the weed dry weight and higher seed rate i.e. 150 kg seed ha\(^{-1}\) recorded taller plants as well as higher grain yield over 100 kg ha\(^{-1}\).

Sriprakash (1996) reported that the integration of 150 kg seed rate ha\(^{-1}\) and post em. Application of isoproturon 0.75 kg + 2, 4-D Na salt 0.5 kg ha\(^{-1}\) (tank mix) was found better than rest of the combination in respect of length of spike and straw yield.

**2.8 ECONOMICS**

Singh et al. (1999) reported from IARI, New Delhi that net profit and benefit –cost ratio in cross were highest row planting by close,
normal and broadcast sowing methods and 125 kg seed ha\(^{-1}\) seed rate gave higher net profit and benefit–cost ratio followed by 150 kg seed ha\(^{-1}\).

Singh et al. (1999) reported from CRS, Ghagrahat (NDUAT, Faizabad) that net income and benefit–cost ratio were highest with cross sowing method followed by unidirectional (15 cm), unidirectional (22.5 cm) and broadcast sowing method. He further reported that crop sown with 150 kg seed rate had highest net income, however, benefit-cost ratio was highest with 125 kg seed ha\(^{-1}\). Singh and Singh (1996) reported from the same place that cross sowing method registered maximum net return followed by closer and normal sowing method. Among herbicidal treatments, tank mix application of isoproturon + 2, 4 – D Na salt (0.75 +0.5 kg ha\(^{-1}\)) gave the highest net return followed by isoproturon applied @1.0 kg ha\(^{-1}\) and pendimethalin applied @ 1.0 kg ha\(^{-1}\).

At NDUAT, Faizabad it has been observed by Sriprakash (1996) that the use of 150 kg seed ha\(^{-1}\) in combination with post-em application of isoproturon 0.75 kg +2, 4 – D Na salt 0.5 kg ha\(^{-1}\) (Tank mix) gave the highest income of Rs. 6405.31 followed by integration of 150 kg seed ha\(^{-1}\) and isoproturon 1.0 kg ha\(^{-1}\) as post-em which gave net income of Rs. 6213.91 per hectare while the lowest net income of Rs. 248.65 was recorded by the combination of 125 kg ha\(^{-1}\) and weedy treatment. Yadava (1999) reported from the same that the cross sowing method + 150 kg seed ha\(^{-1}\) + post-em application of isoproturon 1.0 kg ha\(^{-1}\) gave the highest net become of Rs. 10,268.20.
net income repee⁻¹ investment of Rs. 0.88 and benefit cost ratio of 1.88 in late sown wheat.

Singh et al. (2005) conducted trials on farmers’ field and reported that the zero tillage technology was found to be remunerative by economizing the cost of field preparation to the tune of Rs. 1683 ha⁻¹, reduction of 37 kg ha⁻¹ in seed rate whose worth Rs. 463 and good saving in irrigation amounting to Rs. 350 ha⁻¹ over conventional broadcasting practice. Besides, advancement of 12-18 days in seeding time, it resulted in an increase of yield ranging from 0.90 to 1.60 q ha⁻¹ depending upon sodicity of the soil. As such, overall profitability gain for Rs. 3216 ha⁻¹ attracted the farmers and established the technical feasibility and eco-friendly attributes of the technology.