Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)

गुणवत्ता प्रोटीन मक्का (*जिया मेज* एल.) की उत्पादकता पर खरपतवार प्रबन्धन एवं पोषक तत्व अनुप्रयोग का प्रभाव तथा अनुगामी गेहूँ (*ट्रिटिकम एस्टीवम* एल.) पर उनका अवशिष्टकारी प्रभाव

VERSHA GUPTA

Thesis

Doctor of Philosophy in Agriculture

(Agronomy)

2018

DEPARTMENT OF AGRONOMY
RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
UDAIPUR-313001 (RAJ.)

Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)

गुणवत्ता प्रोटीन मक्का (*जिया मेज* एल.) की उत्पादकता पर खरपतवार प्रबन्धन एवं पोषक तत्व अनुप्रयोग का प्रभाव तथा अनुगामी गेहूँ (*ट्रिटिकम एस्टीवम* एल.) पर उनका अवशिष्टकारी प्रभाव

Thesis

Submitted to the

Maharana Pratap University of Agriculture and Technology, Udaipur

In partial fulfillment of the requirement

for the Degree of

Doctor of Philosophy in Agriculture

(AGRONOMY)

By

VERSHA GUPTA

2018

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR

RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE-I

Dated: / / 2018

This is to certify that **Mrs. Versha Gupta** has successfully completed the Comprehensive Examination held on 13/06/2016 as required under the regulation for the degree of **Doctor of Philosophy in Agriculture.**

(Dr. V. Nepalia)
Professor & Head
Department of Agronomy
Rajasthan College of Agriculture
Udaipur (Rajasthan)

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR
RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE-II

Dated: / / 2018

This is to certify that the thesis entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Agronomy**, embodies bonafide research work carried out by **Mrs. Versha Gupta** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 20/01/2018.

(Dr. V. Nepalia)
Professor & Head
Department of Agronomy

(Dr. Arvind Verma)
Professor &
Major Advisor

(Dr. Arunabh Joshi)
Dean
Rajasthan College of Agriculture,
MPUAT, Udaipur (Rajasthan)

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR
RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

CERTIFICATE-IV

Dated: / /2018

This is to certify that **Mrs. Versha Gupta** student of Doctor of Philosophy in Agriculture, **Department of Agronomy,** Rajasthan College of Agriculture, Udaipur has made all the corrections / modifications in the thesis entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** which were suggested by the external examiner and the advisory committee in the oral examination held on 25 /06 /2018. The final copies of the thesis duly bound and corrected were submitted on / /2018 are enclosed herewith for approval.

(Dr. V. Nepalia)
Professor & Head
Department of Agronomy

(Dr. Arvind Verma)
Professor & Major Advisor
Department of Agronomy

(Dr. Arunabh Joshi)
Dean
Rajasthan College of Agriculture
MPUAT, Udaipur (Rajasthan)

ACKNOWLEDGEMENT

At this moment of accomplishment, first of all I take it to be my proud privilege to express my sincere and deep sense of gratitude and indebtedness to my learned advisor, **Dr. Arvind Verma,** *Professor, Department of Agronomy for his engrossing guidance, incessant encouragement, constrictive suggestions, propitious assistance, keen and sustained interest, kind and gracious patronage during the entire course of investigation and preparation of this manuscript.*

I am highly obliged and gratified to all the members of advisory committee, **Dr. V. Nepalia,** *Professor (Agronomy),* **Dr. S.K. Sharma,** *Professor (Agronomy),* **Dr. H.K. Jain**, *Professor (Statistics & Computer Application),* **Dr. H.S. Purohit,** *Professor (Soil Science) & DRI Nominee, Rajasthan College of Agriculture, Udaipur for their generous gesture and critical suggestions in planning and execution of this study.*

It's my fortune to gratefully acknowledge the support of **Dr. V. Nepalia** *Professor and Head, (Agronomy), Rajasthan College of Agriculture, Udaipur for their keen valuable guidance, regular support and inspiration during the experiment work.*

I would like to express my heartfelt gratitude to **Dr. Arunabh Joshi,** *Dean, Rajasthan College of Agriculture, Udaipur for providing necessary facilities and administrative help in this venture.*

Words fail to recognize the contribution of **Dr. M.K. Kaushik, Dr. Dilip Singh**, **Dr. S.L. Mundra, Dr. N.S. Solanki, Dr. L.N. Dashora, Dr. P.C. Chaplot, Dr. J.X. Massey, Dr. J. Choudhary, Dr. R.S. Choudhary, Dr. Roshan Choudhary, Dr. H.K. Sumeriya, Shri K.S. Shaktawat** *and* **Shri Goverdhan Singh** *and other staff members of the Department of Agronomy for their kind cooperation in completing this investigation smoothly.*

I owe my profound gratefulness to Ex. Faculty members **Dr. Pushpendra Singh, Dr. G.L. Sharma and Dr. R.C. Tiwari** *for their kind and benevolent support during different stages of the study.*

I am highly thankful to Project Incharge, AICRP on Weed Management, Rajasthan College of Agriculture, Udaipur for providing necessary facilities to conduct field experiments, laboratory analysis and permitting me to record the observation for this study from the experiment of the project.

I am indebted to my friends/seniors/juniors for providing a stimulating and fun filled environment. My thanks go in particular to **Sandhya, Suman, Sushila, Priyanka, Manisha, Varsha, Sarita, Santra, Gayatree, Nirmala, Anamika, Jai Prakash, Giriraj, Surendra, Shravan, Naren, Vasudev, V. Shetye, Shankar, Bharat, Amit, Hansram, Narendra, Arif, Bhojraj** *for their ever willing help and co-operation during the course of investigation.*

I would like to pay high regards to my grandfather-in-law **Sh. B.L. Gupta** *and grandmother-in-law* **Smt. Poornima Gupta** *whose inspiration and blessings makes me more energetic at every step of my life for success.*

I feel extremely touched to express my gratitude and respect to my beloved parents, my father **Sh. Bal Govind Gupta**, *and my mother* **Smt. Kamlesh Gupta**. *I owe everything to them and wish I could show them just how much I love and appreciate them. Besides this, my family members like my father-in-law* **Sh. Pramod Gupta,** *mother-in-law* **Smt. Hemlata Gupta** *and all other family members for their special affection and moral support as they have always been a great source of inspiration for me from the very beginning.*

Last but not the least, my most cordial appreciation go to my husband **Mr. Rahul Gupta** *for his patience, cooperation and sacrifice without which the task could not have been a reality.*

Finally, I bow my head in extreme regards to the almighty **"GOD"** *whose wonderful blessings enabled me to reach this destination.*

Place: Udaipur

Date:

(Versha Gupta)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

&	:	And	m^2	:	Square metre
ANOVA	:	Analysis of variance	m^3	:	Cubic metre
B:C	:	Benefit cost ratio	Max.	:	Maximum
CGR	:	Crop growth rate	mg	:	Milligram
C.D.	:	Critical difference	Min.	:	Minimum
cm	:	Centimetre	ml	:	Millilitre
CV	:	Coefficient of variation	mm	:	Millimetre
cv.	:	Cultivar	MSS	:	Mean sum of square
d.f.	:	Degree of freedom	N	:	Nitrogen
DAP	:	Di ammonium phosphate	NS	:	Non-significant
DAS	:	Days after sowing	No.	:	Number
DMA	:	Dry matter accumulation	ºC	:	Degree Celsius
dSm^{-1}	:	Deci simon per metre	ºE	:	Degree east
EC	:	Electrical conductivity	ºN	:	Degree north
et al.	:	(*et alibi*) and else where	P	:	Phosphorus
etc.	:	Etcetera	P_2O_5	:	Phosphorus penta oxide
fb	:	Followed by	$^{-1}$	:	Per
Fig.	:	Figure	%	:	Per cent
f.w.	:	Fresh weight	PE	:	Pre-emergence
g	:	Gram	pH	:	Negative log of H^+ ions activity
ha	:	Hectare	POE	:	Post-emergence
HI	:	Harvest index	q	:	Quintal
hrs.	:	Hours	QPM	:	Quality Protein Maize
HW	:	Hand weeding	₹	:	Rupees
i.e.	:	(id est.) that is	r	:	Correlation coefficient
K	:	Potassium	RDF	:	Recommended dose of fertilizer
K_2O	:	Potassium oxide	RGR	:	Relative growth rate
Kg	:	Kilogram	S.Em.±	:	Standard error of mean
L	:	Litre	T	:	Tonnes
S	:	Sulphur	var.	:	Variety
SC	:	Soluble concentrates	*viz.*,	:	(Vide licet) namely
WP	:	Wettable powder	Zn	:	Zinc

1. INTRODUCTION

Maize (*Zea mays* L.) also called the queen of cereals, is one of the major cereal crops with wide adaptability under various diversified agro-climatic and edaphic conditions around the world. It is the third most important crop after rice and wheat as well as the staple food for vast rural population of India. In India during 2015-16, maize occupied 8.69 m ha area with production of 21.81 m tonnes and an average productivity of 2.51 tonnes ha^{-1} compared to world average of 4.94 tonnes ha^{-1} (Govt. of India, 2016). In our country, Rajasthan ranked first in respect of area, wherein this crop occupied 0.88 m ha area with production of 1.21 m tonnes and productivity of 1.37 tonnes ha^{-1} (Govt. of Rajasthan, 2016). It is a versatile crop which provides food, feed, fodder and serves as source of basic raw material for the number of industrial products *viz.*, starch, protein, oil, alcoholic beverages, food sweeteners, cosmetics, more recently as bio-fuel etc (Krishna, 2012). No other cereal is being used in as many ways as maize. Maize grain is a valuable source of starch (71.8%), protein (10.4%), fat (4.5%), fibre (3%), vitamins like vitamin B group and vitamin C and minerals such as Ca, P, S and Na (Hamayun, 2003). It occupies an important place as a source of human food (25%), animal feed (12%), poultry feed (49%), starch (12%) and in brewery and seed (1% each).

In general maize has low protein content with unbalanced composition of essential amino acids. In this crop, the content of essential amino acids *viz.,* lysine and tryptophan is low while leucine and isoleucine is high (Jat *et al.,* 2013). The low protein and unbalanced amino acids content in maize cause protein deficiency disease like kwashiorkor and malnutrition in the poor class peoples who consume maize as principle dietary source (Singh, 2010). Lysine and tryptophan levels in maize normally do not meet the minimum requirements for human growth (Scoot *et al.,* 2004). In maize, an alcohol soluble protein fraction ‘prolamine’ known as ‘Zein’ is present in endosperm. This zein is high in leusine and isoleusine and low in lysine and tryptophan (Sofi *et al.,* 2009). The high yielding single cross hybrid of quality protein maize developed by breeders at CIMMYT popularly known as ‘QPM’ assumes a great significance in overcoming problem of malnutrition in tribal population of southern Rajasthan as well as in many parts of country where maize is consumed as staple food. There is enormous scope to increase cultivation of QPM further due to increasing global demand, value addition potential and better prices in market compared to traditional varieties of maize. The QPM is a hybrid specially bread by addition of *Opaque* -2 mutant gene, which improves lysine and tryptophan and reduces leucine and isoleucine contents and produce quality protein with balanced composition of amino acids (Prasanna *et al.,* 2001).

Maize in India is mainly cultivated during *kharif* season in which occurence of weed is one of the most important yield limiting factor that significantly reduces the yield. Maize is infested by a wide range of weed flora *viz*., *Echinochloa colona, Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digera arvensis and Trianthema portulacastrum* which compete with the crop throughout its growth period (Saini and Angiras, 1998). However, the most critical period of crop weed competition is the first six weeks after planting of crop when initial slow growth and wider row spacing of maize, coupled with congenial weather conditions allow luxuriant weed growth which may reduce yield by 28-100% (Dass *et al*., 2012). During this critical period, weeding is essentially required by either chemical or non-chemical means. Weeding by hands (labour) and mechanical means is expensive and many a time timely operations are not possible due to continuous rains in monsoon season. So research and development in herbicide technology has opened up new possibilities for integrated weed management practices.

However, application of single herbicide does not provide satisfactory weed control for the desired period. Moreover, continuous use of single herbicide is known to result in the evolution of herbicide-resistance in weed species and shift in weed flora (Thakur and Sharma, 1996, Malviya and Singh, 2007). Atrazine and alachlor have been widely used for effective control of weeds in maize (Tahir *et al*., 2011). However, atrazine used as a pre-emergence, is not effective against some of the grassy and non grassy weeds as well as the sedge *Cyperus rotundus* (Singh *et al.,* 2015). Alachlor also do not control hardy weeds viz., *Brachiaria reptans and Commelina benghalensis* etc (Walia *et al.,* 2007). But continuous use of these herbicides for long time may lead development of herbicide resisitance in weeds (Malviya *et al.,* 2012). Hence, there is need for some alternate post-emergence herbicide like tembotrione which can provide broad spectrum weed control in *kharif* maize without affecting the growth and yield of crop (Singh *et al*., 2012 b). In recent years, maize is grown in rotation with wheat under maize-wheat cropping sequence.

The herbicide applied to maize may leave the residual effect on succeeding wheat crop. But the information on the residual effect of herbicides applied in maize on succeeding wheat is meager.

Maize is also an exhaustive crop and requires several macro and micro nutrients for better growth and yield. Several workers have reported the beneficial effects of NPK fertilization on productivity of maize (Mehta *et al.*, 2005). Amongst various agricultural inputs, fertilizers have been and will continue to be chief input for crop production targets in the country (Prasad *et al*., 1998). Nutrient management also plays key role in sustaining the productivity of this system. Most of the farmers of India apply only major nutrients through fertilizers and that too in irrational quantities which lead to their inefficient utilization by plants. Thus, balanced fertilization is needed for sustaining higher yield. Increased level of production can be achieved by increased and efficient use of inorganic fertilizers.

Judicious use of chemical fertilizers depending upon the availability, nature and properties of the soil and crops to be grown would not only maximize the crop production and improve the quality of agricultural produces but would also help in maintaining the soil fertility, improving productivity and overall health and quality of the soil that sustain the system productivity (Pathak *et al.*, 2005). QPM is high nutrient requiring crop that responds well to higher levels of chemical fertilizers (Singh, 2010 and Om *et al.,* 2014). Adoption of balanced nutrient management to QPM increases the supply and availability of soil nutrients to the crop and will reduce the production cost, thereby increase the economic benefit to the farmers.

Thus higher yield of QPM can be obtained through the judicious and higher doses of two major nutrients (N and P) as these two nutrients alone contribute 40-60 per cent of the crop yield (Das *et al.,* 2010). Among the secondary and micronutrients, S and Zn have specific vital roles in growth and development of crops (Duraisami *et al.,* 2007). It is proven fact that productivity of any crop can not be further increased by use of higher doses of fertilizer alone. So the nutrient management with balanced use of nutrients may improve the yield and also maintains soil health.

Keeping in view the above mentioned factors it was considered necessary to carry out a research trial entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** with the following objectives.

1. To assess the weed management practices on weed dynamics and productivity of QPM.
2. To study the effect of nutrient management on growth and yield of QPM.
3. To work out economics of treatments.
4. To assess the effect of herbicide residues on succeeding wheat crop.

2. REVIEW OF LITERATURE

A compendium of review on available research work done on **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** is presented in this chapter. Since work done on these aspects on QPM is meager, pertinent research findings on maize, speciality corn, sweet corn and other crops have been included wherever felt pertinent.

2.1 Weed management

2.1.1 Crop weed competition

Worldwide maize production is hampered up to 40 per cent by competition from weeds which are the most important pest group of this crop (Oerke and Dehne, 2004). The reduction in maize yield due to presence of weeds is attributed to the crop weed competition for water, light and nutrients (Silva *et al.,* 2004). At INIFAT, Santiago de las Vegas (Cuba), Villasana *et al.* (2004) observed that maize crop must be kept weed free for the first 25-30 days, when weed competition is the greatest. A season long weed infestation resulted in 90 per cent maize yield loss. Walia *et al.* (2005) reported yield losses in maize due to weeds up to 52 per cent owing to wider row spacing and coincidence of crop with rains. At Ontario (Canada), *Amaranthus tuberculates* interference in maize resulted in yield loss up to 38 per cent (Vyn *et al.,* 2006).

Fazil *et al*. (2007) studied the effect of some pre and post emergence herbicides for controlling weeds in maize at Agricultural Research Institute Tarnab, Peshawar (Pakistan) and reported that the herbicides significantly affected weed density, dry weeds biomass, 1000-grain weight and grain yield, while the other parameters showed non-significant differences. At Allahabad (U.P.), a field trial showed that a unit increase in weed population and weed biomass m^{-2} reduced the grain yield by 0.79 and 1.418 q ha^{-1}, respectively. Uncontrolled weed growth throughout the crop growing period caused 43 per cent reduction in grain yield (Singh *et al.,* 2007). Chaudhary *et al.* (2008) at Adaptive Research Farm, Gujaranwala (Pakistan), reported that full season weed infestation caused 47.95 per cent reduction in grain yield as compared to 30 days weed infestation. Critical period of crop-weed competition was found between 30-50 days after sowing (DAS) of wheat.

In a field study under unirrigated conditions in Ottawa (Canada), lack of weed control in maize caused 27 to 38 per cent yield reduction. The weeds also amplified the effect of water stress to the crop during hot summer days, indicating competition for moisture (Subedi and Ma, 2009). Saeed *et al.* (2010) at Faislabad (Pakistan) observed that a weed free maize crop produced 7.42 t ha^{-1} of grain yield, in comparison to yields of 7.06, 6.74, 6.16, 5.43 and 3.76 t ha^{-1} for weed competition with crop for 2, 3, 4, 6 weeks after sowing (WAS) and full season, respectively. In Egypt, a period between 20-35 DAS was estimated to be critical for maize crop and weed competition (Gomaa *et al.,* 2011). Cerrudo *et al.* (2012) in Canada found that presence of weeds in maize field delayed the leaf appearance which caused reduction in trapping photosynthetically active radiation lead to reduction in plant dry matter. The loss in plant dry matter and subsequent inability to accumulate dry matter accounted for rapid decline in kernel number and weight. At Dharwad, uncontrolled weeds caused 33.6 per cent reduction in maize grain yield (Hawaldar and Agasimani, 2012). Field studies conducted for two consecutive years at Ilorin (Nigeria) to evaluate the effect of weed competition in maize crop revealed that maize should be kept weed free for 6-8 WAS (Takim, 2012).

Gantoli *et al.* (2013) in western Atakora, Benin (Germany) observed that the critical period for weed competition in maize started from 4-6 leaf stage and continued upto 10 leaf stage. Subsequently the maize crop yield suffered 38-65 per cent losses depending upon duration of weed infestation. Maize is very susceptible to competition from weeds especially in the early stages of growth; therefore, efficient control at the pre and early post-emergence stages is essential. Once maize attains approximately 0.5 m height, weeds control no longer affect yield (Larbi *et al.*, 2013). Since maize is heavily fertilized and sparsely grown, severe weed infestation is experienced, resulting into a drastic reduction of grain yield (Naidu and Murty, 2014). Dobariya *et al.* (2014) in an experiment on weed management in sweet corn at Junagarh found that infestation of weeds reduced the green cob yield by 29.86 per cent. Similarly, in an experiment on integrated weed management in sweet corn at Agricultural Research Station, Bellary, it was found that infestation of weeds reduced the green cob yield by 54.05 per cent (Shankar *et al.*, 2016).

2.1.2 Effect of atrazine alone or with hand weeding

Effect on weed dynamics

Khajanji *et al.* (2006) found that in maize crop atrazine with one hand weeding at 20 DAS was more effective for weed control. Walia *et al.* (2007) at Ludhiana, in a field experiment recorded significant decrease in dry matter of weeds at harvest due to atrazine with one hand weeding at 40 DAS. At Almora, Uttarakhand, pre-emergence application of atrazine alone or in integration with one hand weeding was found more effective in controlling both grassy and non-grassy weeds and increased yield attributes and yield of maize (Gopinath and Kundu, 2008). Deshmukh *et al.* (2009) in a field experiment at Prabhani observed that atrazine *fb* one hand weeding at 45 DAS significantly reduced weed count and their dry weight at 30, 60 and 90 DAS and resulted in highest weed control efficiency and grain yield. At Tirupati (A.P.), pre-emergence application of atrazine *fb* one hand weeding at 30 DAS significantly reduced density of grasses, sedges and broad leaf weeds and gave highest weed control efficiency (81.25) at 45 DAS (Sunitha *et al.,* 2010).

A field experiment indicated that atrazine at 0.15 kg ha^{-1} and atrazine at 1.25 kg ha^{-1} as pre-emergence + one intercultivation at 30 DAS + one hand weeding at 45 DAS significantly reduced the total weed density and weed dry weight over all weed management treatments except weed free check. It also gave significantly higher grain weight per plant, hundred grain weight and grain yield ha^{-1}. Similar trend was followed in respect of net returns ha^{-1}. Dehydrogenase activity decreased with higher doses of herbicides at 20 DAS (Nadiger *et al.,* 2013). Sharma and Pankaj (2013) reported that the performance of atrazine was better in reducing the population of *Commelina benghalensis, Trianthema portulacastrum* and other weeds. At Jabalpur (M.P.), pre-emergence application of atrazine with one hand weeding at 30 DAS to fodder maize resulted in weed control efficiency of 80.01 per cent (Sanodiya *et al.,* 2014). Swetha *et al.* (2015) in a field experiment at Professor Jayshankar Telangana State Agricultural University, Hyderabad reported that atrazine followed by intercultivation 30 DAS recorded weed control efficiency of 74.3 per cent. In a field experiment at Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, the maximum reduction in biomass of weeds was recorded with atrazine application @1 kg ha^{-1} in maize (Stanzen *et al.*, 2016).

Effect on crop growth, yield attributes, yield and economics

The most economic and effective method of weed control was pre-emergence application of atrazine with one hoeing plus one hand weeding at 20 DAS, which recorded the highest B:C ratio of 1:3.68 (Kamble *et al.,* 2005). Walia *et al.* (2007) at Ludhiana, in a field experiment recorded significant increase in grain and stover yield due to atrazine with one hand weeding at 40 DAS. At Tirupati (A.P.), pre-emergence application of atrazine *fb* one hand weeding at 30 DAS significantly increased cob length, net returns and B:C ratio over rest of the treatment (Sunitha *et al.,* 2010).

At Junagarh Agricultural University, Gujarat, pre-emergence application of atrazine 0.5 kg ha^{-1} with one hand weeding and intercultivation at 30 DAS significantly increased plant height, dry matter $plant^{-1}$, grain weight cob^{-1}, grain yield and fodder yield by 34.4, 43.0, 29.0, 174.3 and 145.7 per cent, respectively over weedy check (Barad *et al.,* 2015). The weed control efficiency and weed index under this treatment was 84.2 and 1.9 per cent, respectively (Barad *et al.,* 2015). Swetha *et al.* (2015) in a field experiment at Professor Jayshankar Telangana State Agricultural University, Hyderabad reported that atrazine followed by intercultivation at 30 DAS recorded maize grain yield of 5.72 t ha^{-1} and B:C ratio of 3.11. Under dryland conditions of Kerawa Kashmir weed management practices of atrazine as pre-emergence application + one hand weeding at 20 DAS was at par with atrazine as pre-emergence + isoproturon as post-emergence application treatment and both showed significant improvement in all yield contributing characters over no weeding and two hand-weedings at 20 and 50 DAS (Gul *et al.,* 2016). Both grain and stover yields were significantly higher with atrazine as pre-emergence application + one hand weeding at 20 DAS over hand weeding on 20 and 50 DAS and no weeding (Gul *et al.,* 2016).

2.1.3 Effect of alachlor alone or with hand weeding

Effect on weed dynamics

Pandey and Prakash (2002) at Almora, Uttarakhand found that alachlor 2 kg ha^{-1} proved better than hand weeding at 20 DAS in controlling weeds. Singh *et al.* (2005) at Udaipur reported that alachlor with one hoeing at 25 DAS was superior in reducing weed population and weed dry matter as well as gave higher maize equivalent yield than hoeing at 25 DAS alone and alachlor at 1.5 kg ha^{-1} alone. Sinha *et al.* (2005) in an experiment at Rajendra Agricultural University, Pusa, Samastipur, Bihar observed that amongst the weed-management practices, nutrient depletion by weeds was minimum under hand-weeding and maximum (22.97 kg N, 4.87 kg P_2O_5 and 27.57 kg K_2O ha^{-1}) in weedy condition, whereas total nutrient uptake by winter maize was maximum (169.41 kg N, 55.67 kg, P_2O_5 and 60.77 kg K_2O ha^{-1}) under the treatment alachlor + French bean as smother crop followed by hand-weeding. Chemical weeding checked nutrient drain by weeds significantly compared with weedy check.

A field experiment was conducted at Faizabad, (U.P.) during 2005 and 2006 revealed that two hand weedings 20 and 40 DAS was most effective with weed-control efficiency (WCE) of 60.74% and 71.78% followed by alachlor + hand weeding at 30 DAS and reduced the weed density and weed biomass significantly, which in turn increased yield compared with weedy check (Malviya and Singh, 2007). Dwivedi *et al.* (2011) at Raipur reported that the highest nitrogen removal by weeds in maize+blackgram intercropping system was recorded under weedy check by all the weed species, while the lowest removal of nitrogen was in alachlor 1.5 kg ha^{-1} + HW at 40 DAS. At harvest stages of blackgram (75 DAS) and maize (105 DAS), dry weight of weeds was lowest with the application of alachlor 1.5 kg ha^{-1} + HW at 40 DAS. This treatment produced maximum grain yield of maize and blackgram, along with higher WCE. Dwivedi and Shrivastava (2011) reported that the highest population of *Alternanthera triandra, Cynodon dactylon, Cyprus rotundus and Cynotis axillaries* in weedy check at 75 DAS which decreased with the advancement in crop age. At important growth stages of crop *i.e.* 50 and 75 DAS and at harvest stage, the maximum reduction in number of total weeds was found with the application of alachlor 1.5 kg ha^{-1} + HW at 40 DAS. At Faizabad, U.P., pre-emergence application of alachlor effectively controlled the weeds and reduced its dry weight as compared to weedy condition (Verma *et al.,* 2015).

Effect on crop growth, yield attributes, yield and economics

Pandey and Prakash (2002) at Almora found that alachlor 2 kg ha^{-1} proved better than hand weeding in producing significantly more maize and soybean grain yields and maize equivalent yield as compared to weedy condition in maize+soybean intercropping system. Meyyappan and Kathiresan (2005) at Annamalainagar observed that in maize+blackgram intercropping system, application of alachlor at 3 kg ha^{-1} *fb* hand weeding at 30 DAS performed significantly superior to twice hand weeding and increased the maize kernel yield by 3.16 times compared to unweeded control.

Dwivedi and Shrivastava (2011) reported that treatment alachlor 1.5 kg ha^{-1} + HW at 40 DAS produced maximum grain and straw yields of maize and net return. Similarly, in field experiments during 2004 and 2005 at Raipur, it was found that at harvest of maize the dry weight of weeds were the lowest with alachlor + hand weeding at 40 DAS. This treatment produced maximum grain yield and production efficiency of maize (Dwivedi *et al.*, 2012). Malviya *et al.* (2012) at Faizabad, U.P. reported that pre-emergence application of alachlor 2.0 kg ha^{-1}+ hand weeding at 30 DAS was effective in controlling weeds with significant increase in grain yield, stover yield, nitrogen uptake and protein yield over weedy check. Based on 2 years study at Jammu, Kour *et al.* (2014) concluded that in winter maize+potato intercropping system, the application of alachlor pre-emergence @ 1.5 kg ha^{-1} was more effective in reducing weed population and resulted in higher economic returns than weedy check. Kour *et al.* (2016) reported that amongst the weed control practices, pre-emergence application of atrazine at 0.5 kg ha^{-1} recorded significantly higher grain yield than weedy check but was statistically at par with pre-emergence application of alachlor at 1.5 kg ha^{-1}.

2.1.4 Effect of tembotrione alone or with hand weeding

Effect on weed dynamics

Tembotrione is currently registered for post-emergence use in corn in the United States and Brazil and has showed quite satisfactory results on weed control, particularly for grasses (Waddington and Young, 2006). Gatzweiler *et al.* (2012) observed that tembotrione alone @ 200 g ha^{-1} was less effective in controlling monocots but when tank mixed with safener isoxadifen-ethyl 200+100 g ha^{-1} effectively controlled both monocot and dicotyledonous weeds. Tembotrione along with safener at two weeks after application was 10 per cent better than without safener. A field experiment was conducted at Pantnagar, during the rainy seasons of 2009 and 2010 to evaluate the efficacy of tembotrione (42% SC), a new post-emergence herbicide against mixed flora in maize as well as its residual effect on growth and yield of the succeeding mustard crop. The experimental field was highly infested with *Echinochloa colona, Digitaria sanguinalis and Cyperus rotundus.* Post emergence application of tembotrione 120 g ha^{-1} along with surfactant was found most effective to control the grassy as well as non-grassy weeds as compared to other herbicidal treatments either applied as pre or post emergence (Singh *et. al.,* 2012 b).

Idziak and Woznica (2014) in the Middle-West Poland observed that herbicide tembotrione applied at reduced rates (44 or 22 g ha^{-1}) with adjuvants and with flufenacet+isoxaflutole herbicide mixture were at par with recommended dose of tembotrione (88 g ha^{-1}) in providing satisfactory weed control in maize in reducing biomass of *Chenopodium album* L., *Viola arvensis* L. and *Brassica napus* L. (96, 100 and 86 per cent, respectively) and gave effective grain yield (10.9 t ha^{-1}). Rana *et al.* (2017) at Palampur, H.P. conducted field trials during 2014 and 2015 to assess the impact of tembotrione on weed growth, yield and economics of maize. They reported that application of tembotrione at 125 and 150 g ha^{-1} with surfactant effectively reduced the dry weight of *Echinochloa colona, Commelina benghalensis, Polygonum alatum, Ageratum conyzoides* and the combined dry weight of all weeds over weedy check.

Effect on crop growth, yield attributes, yield and economics

At Pantnagar, post emergence application of tembotrione @ 120 g ha^{-1} resulted in highest grain yield of maize during both the years of study (Singh *et. al.,* 2012 b). At Bajaura, H.P., PoE application of tembotrione (120 g ha^{-1}) resulted in significantly higher grain yield (5648 kg ha^{-1}), stover yield (7478 kg ha^{-1}) and B:C ratio (2.15) in maize over rest of the treatments (IIMR, 2015). Rana *et al.* (2017) at Palampur, H.P. reported that application of tembotrione at 125 and 150 g ha^{-1} with surfactant resulted in significantly higher grain yield of maize than weedy check.

2.1.5 Effect of herbicide combinations

Effect on weed dynamics

Damalas *et al.* (2004) observed that tank mixture of two or more herbicides is extensively used in intensive agriculture aiming to broaden the spectrum of weed control, to improve efficacy of combined herbicides, to delay resistance development or to reduce herbicide doses. Bijanzadeh and Ghardiri (2006) in Iran reported that application of atrazine + alachlor registered significant reduction in weed biomass and concurrent increase in maize grain yield. Nosratti *et al.* (2007) at Karanj, Iran reported that application of atrazine + alachlor mixture caused significant reduction in weed dry matter in maize. Combined application of atrazine + alachlor was more effective in reducing weed population and weed dry weight as compared to their alone applications. The minimum weed intensity and weed dry weight were observed under application of alachlor (3.5 kg ha^{-1} PE) + atrazine (0.75 kg ha^{-1} PoE), (Singh *et al*., 2007). Joseph *et al.* (2008) reported that tank mix application of post-emergence herbicides *viz.,* topramezone, tembotrione and mesotrione along with atrazine (12+560, 92+560 and 105+560 g ha^{-1}) in maize resulted in excellent control of grassy weeds *viz.,* *Cynodon dactylon* L., *Echinochloa crusgalli* L., *Ambrosia artemisiifolia* L. and *Dactyloctenium aegypticum* L. (98, 96 and 87 per cent, respectively). Changsaluk *et al*. (2009) observed that pre-emergence application of atrazine + alachlor reduced weed density in both sweet corn and field corn.

In a multilocation trial in Iran, the pre-emergence application of atrazine + alachlor at 0.8 + 0.2 kg ha^{-1} and also at 25 per cent reduced rate resulted in 63 and 65 per cent reduction in weed density with concomitant increase in corn yield (Birgani *et al*., 2010). At Tehran University, Iran, application of atrazine+alachlor (1+4 kg ha^{-1}) proved superior in controlling the weeds and in producing higher grain yield of maize (Ghassam *et al.,* 2010). Tank mix application of alachlor + atrazine (1250 g + 375 g ha^{-1}) was found effective in controlling annual weeds in summer maize (Gopal *et al*., 2010). Herbicide mixtures are a useful practice for broad spectrum weed control in maize (Singh *et al.,* 2012 a). Choudhary *et al.* (2013) in field studies of two years observed significant reduction of weed density, dry matter and nutrient uptake by weeds over weedy check. Jonathon *et al.* (2013) observed that tank mix application of tembotrione + atrazine (92+560 g ha^{-1}) as post-emergence recorded 60 per cent reduction in biomass accumulation of *Amaranthus palmeri* and was on par with that of topramezone+atrazine (18+560 g ha^{-1}) and mesotrione+atrazine (105+560 g ha^{-1}). In a greenhouse study, tembotrione + atrazine effectively controlled the glyphosate-resistant kochia accession (Kumar and Jha., 2015).

Effect on crop growth, yield attributes, yield and economics

Application of alachlor + atrazine (1.5+0.5 kg ha^{-1}) as PE gave 53.5 q ha^{-1} of maize yield which was 47.8 per cent higher than weedy check (Sinha *et al.,* 2005). At Anand, Gujarat it was showed that pre-emergence tank mix application of atrazine 0.5 + alachlor 0.5 kg ha^{-1} significantly increased the weed control efficiency, yield attributes, grain yield, stover yield and protein content of maize grain (Patel *et al*., 2006 c). Singh *et al*. (2007) observed significantly higher yield by application of alachlor (3.5 kg ha^{-1} PE) + atrazine (0.50 kg ha^{-1} PoE) over weedy check. In the same experiment, tank mix application of these herbicides significantly increased the plant height, number of cobs ha^{-1}, 1000-grain weight and grain yield of *kharif* maize in comparison to weedy check. It was observed that higher concentration of herbicides had phytotoxic effect on crop plants thereby decreasing yield. Walia *et al*. (2007) at Ludhiana (Punjab) reported that tank mix application of atrazine + alachlor at 0.75 + 1.25 kg ha^{-1} brought about 50.9 and 56.5 per cent increase in maize grain yield during two successive years through better weed control.

Rao *et al*. (2009) at Guntur, A.P. concluded that application of atrazine + alachlor at 0.75 + 1.25 kg ha^{-1} brought about significant reduction in weed density and dry weight but increased plant height of maize at 30, 60 DAS and at harvest with 26.49, 26.10 and 10.34 per cent, respectively, crop dry weight at 60 DAS and at harvest by 44.92 and 16.34 per cent, respectively, number of cobs per plant, 100-seed weight, grain yield (21.81 per cent), net returns (30.10 per cent) and B:C ratio (17.65 per cent) in comparision to weedy check. Martin *et al.* (2011) concluded that tank mix tembotrione with atrazine (31+370 g ha^{-1}) applied at four to five collar stage of corn proved effective for the control of individual weed species by 5 to 45 per cent and yield attributes were also found higher when atrazine was applied with tembotrione.

In Iran, it was found that atrazine + alachlor (1+2.44 kg ha^{-1}) reduced the biomass of different weed species with increase in crop yield attributes and grain yield (Zaremohazabieh and Ghardiri, 2011). Najafi and Ghardiri (2012) in a field experiment at Kooshksk, Iran observed that pre-emergence application of atrazine + alachlor significantly increased the grain yield of maize. Choudhary *et al.* (2013) observed significant increase in yield attributes, yields and N, P, K and S uptake by crop by tank-mix application of atrazine + alachlor. The highest net returns (₹ 40,917 ha^{-1}) was obtained through tank mix atrazine + alachlor (500 + 1500 g ha^{-1}).

Owla *et al.* (2015) at Udaipur, Rajasthan concluded that tank mix application of pre-emergence atrazine + alachlor followed by hoeing and weeding gave the minimum weed density and dry-matter at 30 and 60 DAS in both years in quality protein maize. It also resulted in significantly higher yield attributes, yield (4.48 t ha^{-1}) and net returns (23.34 $\times 10^3$ ha^{-1}). At Professor Jayashankar Telangana State Agriculture University, Hyderabad tank mix application of topramezone (25.2 g ha^{-1})

or tembotrione (105 g ha^{-1}) with lower doses of atrazine at 250 g ha^{-1} along with adjuvants was found effective in controlling the weeds and improving yield in comparision to unweeded control in *kharif* maize (Swetha *et al.,* 2015).

2.1.6 Effect of hand weedings

Effect on weed dynamics

At Kangra, H.P. the results of a field experiment showed maximum reduction in weed density and weed dry weight in hand weeding compared to herbicides (Kumar and Thakur, 2005). Sharana *et al*. (2005) found that hand weeding twice in maize was more effective in controlling weeds in clay loam soil compared to herbicide treatments. At Samastipur (Bihar), two hand weedings at 25 and 45 DAS in maize crop significantly reduced the NPK depletion by weeds in comparison to weedy check as well as herbicide (alachlor at 1.5 + atrazine at 1.5 kg ha^{-1} PE) treated plots (Sinha *et al*., 2005). Malviya and Singh (2007) reported that on silty-loam soils of Faizabad (U.P.), two hand weedings in maize at 20 and 40 DAS was most effective (weed control efficiency 60.74 and 68.31 per cent, respectively) and significantly reduced weed density and weed biomass. Field experiments conducted for two consecutive years to improve maize competitiveness with weeds. With hand hoeing two times (3 and 6 WAS of maize) brought down the dry matter of broadleaf weeds and grasses at 9 WAS from 38.9 and 106.1 g m^{-2} (weedy check) to 5.7 and 1.8 g m^{-2}, respectively (Abouziena *et al*., 2008).

Singh *et al*. (2009 b) at Bijapur (Karnataka) found that two hand weedings in maize at 20 and 40 DAS, tended to significantly reduce the density and dry matter of weeds and accounted for 60.25 and 71.21 per cent weed control efficiency during the two successive years, respectively. Sunitha *et al.* (2010) at Tirupati (A.P.) showed that application of two hand weedings at 15 and 30 DAS in sweet corn significantly reduced density of grasses, sedges and broad leaf weeds at 45 DAS. Hand weeding twice effectively reduced the population of *Commelina sp.* up to 60 DAS (Kumar *et al.,* 2012). In Egypt, 77.3 and 77.7 per cent reduction in total weed density and dry matter, respectively were recorded in comparison to weedy check by two hoeings in maize crop. Concomitantly the crop produced 42.2 per cent higher grain yield (El-Metwally *et al*., 2012).

Choudhary *et al.* (2013) conducted a field experiment during the rainy (*kharif*) seasons of 2009 and 2010 at Udaipur on quality protein maize (*Zea mays* L.) and reported maximum reduction of weed density, dry matter and nutrient uptake by weeds in crop with hand weeding twice at 15 and 30 days after sowing (DAS). At Akola, hand weeding at 20 and 40 DAS resulted in minimum weed population of 42.0 and 30.33 m^{-2} at 60 DAS and at harvest, respectively as well as maximum weed control efficiency and minimum weed index was also obtained with two hand weeding (Sonawane *et al.*, 2014). At Bangalore, in an experiment showed that hand weeding twice at 20 and 40 DAS recorded weed dry weight at harvest to the tune of 89.8 g/0.25 m^{-2} as against unweeded control on the basis of original values (Kumari Geetha *et al.*, 2015).

Effect on crop growth, yield attributes, yield and economics

At Rajendranagar, Hyderabad, Mandal *et al*. (2004) reported that hand weeding twice increased the number of cobs $plant^{-1}$, cob weight, cob yield, green fodder yield, net returns and B:C ratio over weedy check. At Samastipur (Bihar), two hand weedings at 25 and 45 DAS in maize crop brought about 66.6 per cent increase in maize grain yield over weedy check (Sinha *et al*., 2005). Chikoye *et al.* (2006) reported that maize grain yield from hoe-weeded control was among the highest because of good weed control. Khajanji *et al.* (2006) found that weeding twice was better in respect of B:C ratio in comparision to weedy check.

At Salhia (Egypt), in comparison to unweeded control (2.71 t ha^{-1}), two hand hoeings at 3 and 6 WAS resulted in significantly higher (7.19 t ha^{-1}) grain yield of maize (Abouziena *et al*., 2007). Malviya and Singh (2007) reported from Faizabad (U.P.) that two hand weedings at 20 and 40 DAS was most effective with increased yield and highest B: C ratio of maize. Hand hoeing two times at (3 and 6 WAS of maize) increased maize grain yield by 98.4 per cent over unweeded control (Abouziena *et al*., 2008). Prasad *et al.* (2008) in a field experiment at Kanpur recorded the highest weed control efficiency (70.90 per cent) and also maize grain yield increased by 57.48 per cent with manual weeding twice (15 and 30 DAS) in comparision to weedy check.

At Guntur (A.P.), two hand weedings at 15 and 30 DAS recorded the highest plant height at 30 and 60 DAS and at harvest, crop dry weight at 60 DAS and at harvest, number of cobs plant^{-1}, number of seeds cob^{-1}, 1000-seed weight and also gave highest grain yield (105.3 q ha^{-1}), gross return (₹ 68445 ha^{-1}), net return (₹ 50945 ha^{-1}) and B:C ratio (2.9) of maize crop (Rao *et al.*, 2009). Singh *et al*. (2009 b) at Bijapur (Karnataka) reported that two hand weedings in maize at 20 and 40 DAS, produced significantly higher dry matter at 90 DAS and 207.2 and 211.3 per cent more yield over unweeded check in a two years study. The results so exhibited by two hand weedings were at par with those of weed free treatment. Verma *et al.* (2009) at Kanpur observed that two hand weedings at 20 and 40 DAS in maize recorded 75.70 per cent weed control efficiency as well as higher plant height (211.18 cm), dry weight of plant (278.44 g plant^{-1}) and crop growth rate (4.08 g of dry matter day^{-1}) as against weedy check at harvest of crop.

Sharma and Gautam (2010) recorded significantly higher maize yield (26 and 68 per cent) by exercising two hand weedings at 25 and 45 DAS over weedy check at Pantnagar (Uttrakhand). In Egypt, maize produced 42.2 per cent higher grain yield with two hoeings in comparision to weedy check (El- Metwally *et al*., 2012). Choudhary *et al.* (2013) conducted a field experiment during the rainy (*kharif*) seasons of 2009 and 2010 at Udaipur on quality protein maize (*Zea mays* L.) and obtained the highest values of grains row^{-1}, grain weight cob^{-1}, 1000-grain weight, grain (4.55 t ha^{-1}) and stover (7.72 t ha^{-1}) yields and N, P, K and S uptake by crop with two hand-weedings.

At Akola, (Maharashtra), Deshmukh *et al.* (2014) observed highest weed control efficiency (68.12 per cent) and maize grain yield (3.35 t ha^{-1}) with hand weeding twice at 20 and 40 DAS. Duary *et al.* (2015) from West Bengal found that hand weeding twice at 25 and 40 DAS recorded weed control efficiency of 88.8 per cent at 60 DAS and significantly increased number of kernels cob^{-1}, 500 kernel weight and maize grain yield by 49.2, 24.2 and 90.7 per cent, respectively compared to weedy check. At Bangalore, hand weeding twice at 20 and 40 DAS resulted in significant enhancement in kernel yield (44.5 per cent) and 100 kernel weight (18.9 per cent) at harvest compared to weedy check (Kumari Geetha *et al.,* 2015). Shrinivas *et al.* (2015) at Malnoor, Yadagir (Karnataka) recorded weed control efficiency of 38.08 per cent and significant increase in maize yield by 78.93 per cent with hand weeding twice 20 and 40 DAS over weedy check.

2.2 Nutrient management

2.2.1 Effect on growth parameters

Pathak *et al.* (2002) conducted an experiment on loamy soils of Ranchi (Jharkhand) and observed significant increase in plant height, leaf area index (LAI), dry matter accumulation, net assimilation rate (NAR) and crop growth rate (CGR) with 100% recommended NPK (100:50:25 kg ha^{-1}) over control in maize.

On sandy loam soils of Varanasi (U.P.) application of 180, 90 and 60 kg ha^{-1} of NPK significantly improved growth parameters of maize over control (Sutalia and Singh, 2005). Sahoo and Mahapatra (2005) reported accelerated plant growth and development of maize with the application of fertilizers. An experiment conducted on sandy clay loam soil of Udaipur (Rajasthan) revealed significant increase in plant height, LAI, dry matter accumulation at 30, 60 and 90 DAS and CGR of maize with application of N, P_2O_5 and K_2O at 90, 30 and 15 kg ha^{-1}, respectively over control (Verma *et al*., 2006). At Udaipur (Rajasthan), Dadarwal *et al.* (2009) reported that 150% RDF significantly increased plant height and dry matter accumulation of baby corn over 100% RDF (120:40:30 kg ha^{-1} N:P_2O_5:K_2O). On clay loam soil of Udaipur (Rajasthan) application of recommended dose of N, P_2O_5, and K_2O significantly improved plant height (200 cm) and LAI (2.79). However, dry matter accumulation at harvest and CGR between 45 to 75 DAS of quality protein maize increased significantly up to 125% RDF (Singh *et al*., 2009 a).

An application of RDF (120 kg N + 90 kg P_2O_5 + 60 kg K_20 ha^{-1}) resulted in significantly greater plant height of maize over control and other doses and combination of fertilizers (Dilshad *et al*., 2010). Kumar and Dhar (2010) conducted a field experiment at Indian Agricultural Research Institute (IARI), New Delhi during 2004-06 on sandy-loam soil and reported significantly maximum leaf area index (4.05%) and dry weight $plant^{-1}$ (119.3 g) of maize with the application of RDF (120 N + 26 P + 32 K kg ha^{-1}) as compared to other treatments. Another study on sandy loam soil of IARI, New Delhi revealed the maximum LAI and dry weight $plant^{-1}$of maize with application of recommended dose of fertilizer (100 kg N, 26 kg P_2O_5 and 32 kg K_20 ha^{-1}) over control (Kumar and Pitchari, 2010). Srinivasrao *et al.* (2010) conducted a field experiment during 2000-04 at Indian Institute of Pulses Research, Kanpur. They reported that plant height (182.1 cm) and dry matter production (6,493 kg ha^{-1})

of maize were significantly higher under the application of 20 kg S ha^{-1} as compared to rest of the treatments.

At Aklera, Jhalawar in two consecutive rainy seasons of 2008 and 2009, application of 150% RDF (N_{60} $P_{22.5}$) produced significantly higher maize plant height (207.3 cm), dry matter (149.1 g plant^{-1}) compared to control (Tetarwal *et al.*, 2011). At Kerawa, (Kashmir) significant increase in LAI and dry matter of maize was obtained with application of NPK (Gul *et al.,* 2015). Joshi *et al.* (2016) observed that the STCR-based application of N, P, K and Zn (120, 60, 40, 5.5 kg ha^{-1}) resulted in significantly higher dry-matter accumulation compared to all the other treatments in both years of study. The treatment NPK (–Zn) applied to maize resulted in significantly higher dry-matter accumulation than the plots fertilized with N alone, NP and NPZn. The similar trend was also observed for cumulative effect of NPK application.

2.2.2 Effect on yield attributes and yield

In the rainfed condition of Kangra (H.P.) during *kharif* season on clay loam soil, application of 150% NPK (180:90:60 kg ha^{-1}) significantly increased the grain yield, straw yield, test weight, grains cob^{-1} and cobs ha^{-1} of maize over control (Kumar *et al.,* 2002). At Ranchi (Jharkhand), Pathak *et al*. (2002) observed significant increase in cobs per plant, cob length, cob girth, grains cob^{-1}, 1000-grain weight and grain yield of maize with application of 100% NPK over unfertilized control. In an experiment conducted on Typic Ustochrept of Kanpur, application of Zn up to 5 kg ha^{-1} significantly increased the maize grain and stover yield over unfertilized control. Similarly, soil application of S up to 30 kg ha^{-1} significantly enhanced the maize grain yield over control (Dwivedi *et al.,* 2002).

At sandy soil of New Delhi, yield of maize increased significantly with 100% RDF (120, 60, 40 and 5 kg ha^{-1} of N, P_2O_5, K_2O and Zn) over the control (Ahlawat *et al.*, 2005). Mehta *et al*. (2005) conducted an experiment on clay loam soil of Udaipur (Rajasthan) and reported that application of 60 kg sulphur ha^{-1} to maize crop recorded significantly higher seed and stover yield over control and 30 kg S ha^{-1}. Experiment conducted on red sandy loam soil of Mayurbhanj (Orissa) indicated significant increase in number of cobs, weight of cob and yield of green cob of maize with increasing levels of fertilizer (Sahoo and Mahapatra, 2005). Experiment conducted on sandy loam soil of Varanasi (Uttar Pradesh) showed that fertility level up to 180, 90 and 60 kg ha^{-1} of N, P_2O_5 and K_2O significantly improved yield and yield attributes of maize over lower levels. The increase in maize grain yield was 52.6 and 82.97% with 120, 60, 40 kg N, P_2O_5 and K_2O ha^{-1} and 180, 90, 60 kg N, P_2O_5 and K_2O ha^{-1}, respectively, over 60, 30 and 20 kg N, P_2O_5 and K_2O ha^{-1} (Sutalia and Singh, 2005).

Saha and Mondal (2006) in West Bengal observed that 100% RDF significantly increased plant height, yield and protein content in baby corn in two years of study. On sandy clay loam soil of Udaipur (Rajasthan), highest maize grain and stover yields were obtained by applying 150% NPK (Verma *et al.*, 2006). In an experiment at Jashipur, (Orissa) during *kharif* on well drained sandy clay loam soil, significant increase in weight of green cob, grains cob^{-1}, green cob yield, green fodder yield, net profit and B:C ratio of sweet corn were recorded with the application of 120 + 26.2 + 50 kg NPK ha^{-1} (Sahoo and Mahapatra, 2007). On the medium black soil of Thane, (Maharashtra) an application of RDF (225:60:60 kg N, P_2O_5 and K_2O ha^{-1}) to sweet corn resulted in significantly higher values of all the yield attributing characters and yield than control (Gosavi *et al.*, 2009). Srikanth *et al.* (2009) at Coimbatore (T.N.) obtained the highest grain yield (6485 kg ha^{-1}) and stover yield (11093 kg ha^{-1}) of hybrid maize with the application of (250:125:125 kg N, P_2O_5 and K_2O ha^{-1}). At Udaipur, Singh *et al*. (2009 a) reported significant improvement in grain and stover yield of quality protein maize by application of 125% RDF by 7.60, 40.71 over 100% and 8.62, 43.23% over 75% RDF, respectively. However, cobs plant^{-1}, grains cob^{-1}, test weight, cob length responded significantly up to 125% RDF.

Behera and Singh (2010) reported significant increase in grain and stover yields of maize with application of 100% NPKZn over control. Application of 125% of RDF (150 kg N, 26.4 kg P and 33.3 kg K ha^{-1}) resulted in significantly higher baby corn yield over RDF (Paradkar *et al*., 2010). At Varanasi (U.P.) application of 180 kg N + 38.7 kg P and 74.7 kg K to baby corn through chemical fertilizers gave statistically equivalent yields (Singh *et al.*, 2010). At Kanpur, mean maize grain yield was increased by 29.7 per cent when 20 kg S ha^{-1} was applied compared to no sulphur application (Srinivasrao *et al.*, 2010). In Tamil Nadu, highest grain yields (8.15 and 7.71 t ha^{-1}) were recorded in the treatments comprising 250:60:25:10 and 250:76:88:7.4 kg of NPK and Zn ha^{-1} (Paramasivan *et al.*, 2011). Tetarwal *et al.* (2011) reported significantly higher number of cobs plant^{-1} (1.4), number of grains cob^{-1} (209), grain (3.22 t ha^{-1}) and biological (8.23 t ha^{-1}) yield, net return (₹ 19,251 ha^{-1}) and B:C ratio (1.90) with 150% RDF (N_{60} $P_{22.5}$) as compared to control. At Chhindwara, (M.P.), Choudhary *et al.* (2012) found that the raising rate of nutrient application to quality protein maize significantly increased the grain yield (26.3 per cent) and net returns (23.0 per cent) over lower dose. At Udaipur soil application of 40 kg S ha^{-1} in addition to RDF (120 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1}) failed to influence maize yield in comparison to RDF alone (Joshi, 2012). Another study at Chhindwara, (M.P.), showed that application of 150% RDF (180:90:60) resulted in 26.3 per cent higher QPM grain yield and 23.0 per cent higher net returns over 100% RDF (Verma *et al.*, 2012).

At Hyderabad (A.P.), application of 240 kg N ha^{-1} significantly improved yield attributing parameters, grain and stover yield over 180 kg N ha^{-1} (Jena *et al.*, 2013). At Varanasi (U.P.), application of 160 kg N ha^{-1} significantly enhanced length of cob, girth of cob, shelling per cent, grain and stover yields over control. (Om *et al.*, 2014). In a field experiment during the rainy (*kharif*) seasons of 2012 and 2013 at New Delhi, integrated application of phospho-enriched compost and chemical fertilizers and soil application of $ZnSO_4$ at 12.5 kg ha^{-1} with a foliar application of $ZnSO_4$ at silking stage were found as the best treatments for improving yield and quality of maize (Paramesh *et al.*, 2014).

Gul and Khanday (2015) at Kashmir observed that application of NPK (90:40:60 kg ha^{-1}) significantly increased cobs plant^{-1}, grains cob^{-1}, number of grain rows cob^{-1}, grain yield and stover yield of maize over control. In the other experiment at Kerawa, (Kashmir), Gul *et al.* (2015) reported significant increase in grains cob^{-1}, number of grain rows cob^{-1}, grain yield and stover yield of maize with application of NPK (90:60:40 kg ha^{-1}) by magnitudes of increase was 5.05, 19.66, 5.21 and 3.71 per cent, respectively over control. In a field experiment during the rainy seasons of 2012 and 2013 on a noncalcareous alkaline sandy clay loam soil, application of NPKZn using STCR approach resulted in the highest values of cob length, cobs plant^{-1}, grains cob^{-1}, grain weight cob^{-1}, total weight of cobs and 1,000-grain weight of maize over recommended doses of NPKZn (Joshi *et al.*, 2016). The STCR-based nutrient application increased grain yield by 5.8 per cent in 2012 and 5.7 per cent in 2013, respectively over balanced fertilization.

2.2.3 Effect on nutrient content, uptake and quality

Misra *et al.* (2001) observed that the crop fertilized with 100% NPK produced 10 per cent protein which was 3.6 per cent significantly higher by over other lower doses. At Udaipur (Rajasthan), Tak (2000) found significant increase in N, P, K, Zn, Fe, Cu, Mn content in maize plant at various crop growth stages with increasing fertility levels. Application of Zn at 10 kg ha^{-1} showed significant positive effect on N, P, K and Zn content and uptake as compared to control. Application 100% of the recommended dose of N, improved the content of major (N, P, K) and minor (Zn, Cu, Fe, Mn) nutrients in grain and stover of maize crop in comparision to control (Totawat *et al*., 2001).

On sandy loam soil of IARI, New Delhi the uptake of N, P and K by grain and stover of maize were influenced significantly due to varying fertility levels. The application of 120:60:50 kg N, P_2O_5 and K_2O ha^{-1} gave the maximum uptake of N, P and K by grain and stover (Karki and Kumar, 2004). Sutalia and Singh (2005) in an experiment on sandy loam soil of Varanasi (Uttar Pradesh) reported that application of 180, 90 and 60 kg N, P_2O_5 and K_2O ha^{-1} significantly increased uptake of N, P and K by maize grain over control. A field experiment conducted at Udaipur showed that application of 150% NPK significantly enhanced nutrient uptake (19.65, 25.89 and 14.78 per cent NPK, repectively) by maize over 100% NPK (Verma *et al*., 2006). An experiment conducted at Jashipur, (Orissa) during *kharif* on well drained sandy clay loam soil revealed significant increase in nutrient uptake of sweet corn with the application of 120 + 26.2 + 50 kg NPK ha^{-1} (Sahoo and Mahapatra, 2007). Singh and Yadav (2007) at Udaipur observed that protein content in maize grain on clay loam soil increased significantly up to 125% RDF which was 6.41 percent higher over other levels. At New Delhi, application of 40, 80 and 120 kg ha^{-1} of N increased nitrogen uptake by 46.5, 78, and 99 per cent in maize crop (Kumar, 2008).

On the medium black soil of Thane, (Maharashtra), application of RDF (225:60:60 kg N, P_2O_5 and K_2O ha^{-1}) significantly increased protein content in sweet corn by 46.81 per cent than control (Gosavi *et al.*, 2009). Behera and Singh (2009) at IARI, New Delhi reported significantly higher total uptake of Zn by maize with 100% NPK + Zn (268.6 Kg ha^{-1}) than 100% NPK (165.4 kg ha^{-1}). At IARI New Delhi, Behera and Singh (2010) reported that application of 100% recommended dose of NPK significantly influenced the total uptake of Zn, Fe, Mn and Cu respectively by maize crop over control. Kumar and Dhar (2010) also at IARI, New Delhi obtained highest NPK uptake with the application of 120 kg N + 26 P + 32 K kg ha^{-1} in two successive years of 2004 and 2005.

Balai *et al.* (2011) at Udaipur found that application of 150% NPK as per soil test fertilizer recommendation recorded significantly higher protein content in grain of maize over control. Tetarwal *et al*. (2011) reported significantly higher N, P and Zn uptake with 150% RDF (N_{60} $P_{22.5}$) as compared to control. In Tamil Nadu, the nutrient uptake by maize crop was significantly influenced by rate of nutrient application. Treatment with 250:76:88:7.4 of NPK and Zn significantly increased N and Zn uptake while the treatment comprising 200:95:88:7.4 of NPK and Zn significantly increased P and K uptake by maize crop on farmers' fields over control (Paramasivan *et al.,* 2012). At IARI, Delhi, application of 225 kg N + 135 kg P_2O_5 + 135 kg K_2O + 60 kg S + 15 kg Zn ha^{-1} significantly increased N, P, K, S and Zn uptake in comparision to crop (Manea *et al.*, 2015).

2.3 Residual effect of herbicides

Carryover effect of atrazine + alachlor (2860 + 2860 g ha^{-1}) applied to preceding maize crop was observed on succeeding rape (canola) crop. Rape germination and shoot dry biomass production were adversely affected at initial days after application. However, phytotoxity symptoms decreased gradually and after 90 DAS, no negative effects were observed for the parameters evaluated (Oliveiria Junior, 2001). On the basis of fresh weight of oat plants at the end of incubation period of 60 days, the level of inactivation of atrazine in investigated soils was more decaying in vertisol than other soil types (Milcic *et al*., 2003).

Several research findings indicated that atrazine application at recommended doses in maize did not leave any residues to affect succeeding crops like chickpea, cowpea, groundnut, Indian mustard, wheat, linseed and lentil (Reddy and Tyagi, 2005). Pre-emergence application of pendimethalin at 0.25 kg ha^{-1} with either atrazine or alachlor at 0.5 kg ha^{-1} to preceding maize crop had no adverse effect on succeeding *rabi* oat and mustard crop (Patel *et al*., 2006 b).The bioassay studies in Gujarat revealed that there was no residual effect of pre-emergence application of atrazine + alachlor (0.5 + 0.5 kg ha^{-1}) and atrazine + pendimethalin (0.5 + 0.25 kg ha^{-1}) herbicides on succeeding oat and mustard plants (Patel *et al*., 2006 a). Results of field investigation carried out during two consecutive years at Kanpur (U.P.) revealed that atrazine at 0.50 kg ha^{-1} applied to maize had no residual effect on the germination and plant stand of succeeding greengram as well as associated weeds (Verma *et al.*, 2009).

A greenhouse study conducted at University of Tehran to assess residual effect of atrazine + alachlor (1+ 4 kg ha^{-1}) herbicides applied in combination or alone revealed that atrazine caused more reduction in germination, amount of dry weight and shoot length of maize (Ghassam *et al.*, 2010). Smith (2010) from Alberta, Canada found that during dry years, atrazine severely injured wheat and lentil crops, seeded one year after herbicide application, on upper slope locations. While in years with high rainfall, no crop injury occurred one year after atrazine application on either upper or lower slope locations in both no-tillage and conventional tillage systems.

A pot experiment was carried out under controlled conditions to evaluate the residual effects of different doses of atrazine+alachlor used in corn fields on the growth and physiology of rapeseed and results showed that rapeseed is quite sensitive to the residues of atrazine+alachlor (Peyvastegan and Farahbakhsh, 2011). Compared to weed free and weedy check, an application of atrazine at 0.5 kg + alachlor at 0.5 kg ha^{-1} to maize crop did not exhibit any significant adverse effect on grain yield of succeeding wheat crop, indicating dissipation of these herbicides before planting of next crop in rotation after maize (IIMR, 2011). While working in maize-wheat rotation, Holford *et al.* (2012) found that atrazine applied in maize did not damage succeeding wheat crop under sufficiency of nitrogen. At Pantnagar, application of tembotrione (42% SC) to maize during the rainy seasons of 2009 and 2010 did not cause residual effects on the growth and yield of succeeding mustard crop (Singh *et al.*, 2012 b).

A glasshouse experiment conducted at Islamic Azad University during 2009-2010 revealed that application of atrazine+alachlor mixture to corn significantly reduced growth parameters of succeeding wheat at all concentrations of atrazine+alachlor compared to untreated control(Yazdanpak *et al.*, 2014). The stunting was linearly increased with increasing percentages of herbicide residue. However, all plants were died at more than 50% residues of atrazine+alachlor.

Li Yu *et al.* (2015) in Ontario, Canada, conducted a field experiment to characterize the effects of soil residues of selected herbicides on establishment and growth of spring wheat (*Triticum aestivum* L.). When *S*-metolachlor or atrazine plus mesotrione (2880+140 and 5760+280 g ha^{-1}) was applied pre-emergence to sweet corn (*Zea mays* L.), there was no observable adverse effects of visible injury, light attenuation, shoot dry weight, and nitrate-nitrogen content on spring wheat regardless of herbicide. The bioassay studies at Shimoga (Karnataka) revealed that different pre and post emergence herbicides *viz.* atrazine and tembotrione applied to maize did not show any observable phytotoxicity symptoms on the succeeding green gram crop (Umesha *et al.,* 2015). Weed biomass and cowpea biomass were not affected by the residual atrazine as the atrazine could have been leached beyond the rooting zone (Chikutuma *et al.,* 2015).

Bontempo *et al.* (2016) observed that the presence of atrazine and tembotrione decreased shoot dry mass in the area, and only tembotrione reduced total root productivity indicating the carryover effect of tembotrione application that reduced the dry matter accumulation of shoot and total productivity, and atrazine + tembotrione (100.8 g ha^{-1}) mixture reduced the total productivity after application of these herbicides to soil.

3. MATERIALS AND METHODS

The field experiment entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"**was conducted during 2015-16 and 2016-17 at Rajasthan College of Agriculture, Udaipur. The details of experimental techniques and materials used and criteria adopted for treatment evaluation during the course of investigation are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiments during both the years were laid out at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur. The site is situated at South-Eastern part of Rajasthan at an altitude of 579.5 metre above mean sea level with 24º35' N latitude and 74°42' E longitude. The region falls under agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan.

3.2 CLIMATE AND WEATHER CONDITION

This zone possesses a typical sub-tropical climatic conditions characterized by mild winters and moderate summers associated with high relative humidity during the months of July to September. The mean annual rainfall of the region is 637 mm, most of which is contributed by South-West monsoon (80-85 per cent) from July to September. In summers, maximum temperature goes up to 44^{o}C. May and June are the hottest months. Minimum temperature during December and January falls as low as 1ºC. Winters are generally rainless. The mean weekly meteorological observations recorded at Agromet Observatory, Rajasthan College of Agriculture, Udaipur during cropping periods are presented in Table 3.1 (a) & (b) and depicted in Fig. 3.1 and 3.2. The perusal of data reveal that the maximum and minimum temperatures during the crop growth period ranged between 28.5 ºC to 35.9 ºC and 16.6 ºC to 26.2 ºC, respectively during the *kharif,* 2015. The corresponding fluctuations during second year (*kharif,* 2016) of experimentation were 26.8 ºC to 35.3 ºC and 17.9 ºC to 24.3 ºC. The wheat crop experienced the minimum temperature varied between 4.0 ºC and 17.9 ºC and from 5.6 ºC to 15.1 ºC while the maximum temperature between 23.7 ºC and 35.9ºC and from 20.9 ºC to 34.1 ºC during 2015-16 and 2016-17, respectively. The total rainfall received during maize crop growth period in 2015 and 2016 was

442.2 mm and 627.1mm, respectively. While wheat crop received total rainfall of 0.0 and 0.2 mm during its growth period in the year 2015-16 and 2016-17, respectively. The minimum and maximum relative humidity during maize crop ranged between 24.0 and 88.1 per cent and between 62.6 and 92.1 per cent in the year 2015 and 30.4 to 89.0 and 72.0 to 95.0 per cent in the year 2016, respectively. While during wheat crop relative humidity ranged between 17.9 and 35.0 per cent and 51.7 and 83.6 per cent in the year 2015-16 and 17.4 to 47.0 per cent and 63.0 to 92.1 per cent in the year 2016-17, respectively.

3. 3 PHYSICO-CHEMICAL PROPERTIES OF EXPERIMENTAL SOIL

The soil samples were randomly drawn from different spots of experimental site up to 15 cm depth before the start of experiment during each year and composite sample was prepared after proper mixing, drying and sieving. The composite soil sample was analysed for different physico-chemical characteristics of the experimental soils. The values of soil analysis along with methods followed have been furnished in Table 3.2. The data show that soil of experimental site was clay loam in texture and slightly alkaline in reaction. The soil was medium in available nitrogen and phosphorus, while high in available potassium and DTPA extractable zinc and low in available sulphur.

3.4 CROPPING HISTORY

The experimental field was under continuous cropping for the last many years. Wheat crop was taken in the experimental area in preceding *rabi* season followed by the present experiment in *kharif* season during both the years.

3.5 EXPERIMENTAL DETAILS

3.5.1 Treatments

(A) Weed management (In main plots) **Symbol**

I.	Weedy check	W_1
II.	Hand weeding at 15 DAS and 35 DAS	W_2
III.	Tembotrione 0.125 kg ha^{-1} at 20 DAS	W_3
IV.	Alachlor 2.0 kg ha^{-1} as PE *fb* hand weeding at 35 DAS	W_4

V.	Atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS	W_5
VI.	Tembotrione 0.125 kg ha^{-1} at 20 DAS *fb* hand weeding at 35 DAS	W_6
VII.	Alachlor 2.0 kg ha^{-1} + atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS	W_7
VIII.	Alachlor 2.0 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS	W_8
IX.	Atrazine 0.5 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS	W_9

(B) Nutrient management (In sub plots)

I.	NPK	F_1
II.	NPK+Zn	F_2
III.	NPKS+Zn	F_3

N: 120 kg N ha^{-1}, P: 60 kg P_2O_5 ha^{-1}, K: 30 kg K_2O ha^{-1}, S: 40 kg S ha^{-1}, Zn: 5 kg ha^{-1}

3.5.2 Other experimental details and layout

Experimental design	:	Spit Plot Design Main plot: Weed control Sub plot: Nutrient management
Replications	:	3
Total number of treatment combinations	:	27
Total number of plots	:	81
Plot size	:	Gross: 5.0 m x 3.6 m = 18.0 m^2 Net: 4.0 m x 2.4 m= 9.6 m^2
Test crop	:	Quality Protein Maize and Wheat
Variety	:	Maize cv. Pratap QPM-1 and Wheat cv. Raj-4079
Crop geometry	:	60 cm x 25 cm for QPM and 22.5 cm for wheat
Seed rate	:	20 kg $ha^{-1}$for QPM and 100 kg ha^{-1} for wheat
Nutrient application	:	As per treatments

3.6 DETAILS OF CROP RAISING

Details of field operations carried out for maize and wheat are given in Table 3.3 and 3.4, respectively.

Table 3.3: Schedule of operations during crop growing period of maize

Operations	**Year**	
	2015	**2016**
Field preparation	05.07.2015	30.06.2016
Layout and bunding	06.07.2015	02.07.2016
Opening of furrows and Sowing	07.07.2015	03.07.2016
Fertilizer placement		
Basal	07.07.2015	03.07.2016
Top dressing	23.07.2015	30.08.2016
Atrazine and alachlor as PE spray (As per treatment)	08.07.2015	04.07.2016
Thinning	20.07.2015	15.07.2016
Hand weeding at 15 DAS (As per treatment)	22.07.2015	18.07.2016
Tembotrione spray at 20 DAS (As per treatment)	27.07.2015	23.07.2016
Hand weeding 35 DAS (As per treatment)	18.08.2015	14.08.2016
Irrigation		
First	23.07.2015	30.08.2016
Second	31.08.2015	01.09.2016
Harvesting	28.10.2015	15.10.2016
Threshing and Winnowing	06.11.2015	10.11.2016

Table 3.4: Schedule of operations during crop growing period of wheat

Operations	**Year**	
	2015-16	**2016-17**
Field preparation	17.11.2015	06.11.2016
Layout and bunding	18.11.2015	07.11.2016
Sowing	19.11.2015	08.11.2016
Fertilizer placement		
Basal	19.11.2015	08.11.2016
Top dressing	10.12.2015	30.11.2016
Irrigation		
Post-sowing irrigation	19.11.2015	08.11.2016
First irrigation	10.12.2015	30.11.2016

Second irrigation	30.12.2015	20.12.2016
Third irrigation	21.01.2016	12.01.2017
Fourth irrigation	16.02.2016	08.02.2017
Fifth irrigation	10.03.2016	05.03.2017
Harvesting	30.03.2016	22.03.2017
Threshing and Winnowing	08.04.2016	01.04.2017

3.6.1 Field preparation

After the harvest of *rabi* wheat, the field was ploughed with tractor drawn disc plough and left fallow during summer. With the onset of monsoon field was prepared by cross harrowing followed by planking to obtain well levelled pulverized soil. The plots were demarcated along with paths and irrigation channels and bunds were prepared to separate each experimental unit as per layout plan depicted in Fig.3.3.

3.6.2 Fertilizer application

As per the treatments full dose of phosphorus, potassium, sulphur and zinc and half dose of nitrogen were applied as basal application at time of sowing through urea, DAP, mineral gypsum and zinc sulphate monohydrate. The remaining dose of nitrogen was top dressed at knee height stage of maize through urea.

3.6.3 Seed and sowing

The Quality Protein Maize hybrid Pratap QPM-1 was sown at the seed rate of 20 kg ha^{-1} at inter row spacing of 60 cm and plant to plant spacing of 25 cm was maintained by thinning. Furrows were opened with desi plough and seeds were sown manually at the depth of 5 cm. Before sowing seeds were treated with carbendazim @ 2.0 g kg^{-1} seed to protect it from fungal diseases.

3.6.4 Weed management

As per treatments, both atrazine and alachlor were sprayed one day after sowing (as pre-emergence) while tembotrione was applied twenty days after sowing (as post-emergence). These herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 500 litres of water per hectare. In the plots involving hand weeding treatment, the weeds were removed manually on scheduled dates as per treatment. The list of herbicides and their formulation used has been given in Table 3.5.

Table 3.5: Details of herbicides used

S.No.	Common Name	Trade Name	Chemical Name
1.	Atrazine	Solaro 50% WP	6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine
2.	Alachlor	Lasso 50% WP	2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl) acetanilide
3.	Tembotrione	Laudis 42% SC (34.4% W/W)	2-[2-chloro-4-(methylsulfonyl)-3-{(2,2,2-trifluoroethoxy)methyl}benzoyl]-1,3-cyclohexanedione

3.6.5 Thinning

In order to maintain plant to plant distance of 25 cm, thinning was done about fifteen days after sowing.

3.6.6 Irrigation

In both the years, during entire maize growth period, two life saving irrigations were applied after sowing, one was given at knee high stage and further to ensure proper maturity one more irrigation was given at grain filling stage.

3.6.7 Harvesting and threshing

The crop was harvested along with cobs when plant turned golden yellow with the help of sickle. The plants of crop from border areas were harvested first, collected and removed from each plot. Then net plot crop was harvested close to ground and plants were tied in bundles and kept for sun drying on threshing floor for few days. After sun drying of harvested plants of net plot area, cobs were separated from individual plant. After separation of the cobs from plants, they were dehusked and shelled through cob sheller and produce of each plot was winnowed and weighed. The weight was recorded and converted into kg ha^{-1}.

3.6.8 Succeeding wheat

After harvest of maize, the field was irrigated and prepared for wheat sowing. The plots were demarcated precisely on the same points as they were done for maize crop. The experimental field was prepared for sowing without disturbing the original layout. After final preparation of the field, wheat cv. Raj 4079 was sown in lines at 22.5 cm spacing using 100 kg seed ha^{-1}. The wheat crop was fertilized with recommended dose of fertilizer (N_{120} P_{60} K_{40}). Entire amount of phosphorus and potassium and 50 per cent N were applied as basal application and remaining 50 per cent N was applied into two equal splits after first and second irrigation. Five irrigations were applied at the most critical stages of the crop in addition to pre-sowing irrigation during both the years. During the crop period up to 45 DAS, no inter cultivation operation was performed in wheat because of residual study of previous crop on wheat. Harvesting was done when plants turned yellow and produce of net plot was tied in bundles and left for sun drying on threshing floor for few days. Thereafter, these bundles were weighed to record biological yield and then crop bundles were threshed to obtain grain and straw yields. The yields were expressed in kg ha^{-1}. Details of cultural operations are given in Table 3.4.

3.7 TREATMENT EVALUTION

In order to evaluate effect of treatments on growth, yield attributes, yield, nutrient content and their uptake, observations were recorded for each parameter as per below methodology.

3.7.1 Weed studies

Each plot in the experiment was surveyed at two places using 0.25 m^2 quadrate for studying weed composition in the experiment. A list of dominant weed species found during the period of investigation is presented in Table 3.6.

Table 3.6: Weed flora of experimental site

S. No.	Botanical name	English name	Family	Growth habit*
1.	*Amaranthus viridis* L.	Slender amaranth	Amaranthaceae	ADRs
2.	*Commelina benghalensis* L.	Day flower	Commelinaceae	ADRs
3.	*Cynodon dactylon* (L.) Pers.	Bermuda grass	Poaceae	PMRsRv
4.	*Cyperus rotundus* L.	Purple nutsedge	Cyperaceae	PMRsRv
5.	*Digera arvensis* Forsk.	Kondra	Amaranthaceae	ADRs
6.	*Dinebra retroflexa* (Vahl) Panz.	Viper grass	Poaceae	AMRs
7.	*Echinochloa colona* (L.) Link.	Jungle rice	Poaceae	AMRs
8.	*Brachiaria reptans* (L.)	Running grass	Poaceae	AMRs

S. No.	Botanical name	English name	Family	Growth habit*
9.	*Trianthema portulacastrum* L.	Horse purslane	Aizoaceae	ADRs

* Asterisk details:

A = Annual	P = Perinnial
D = Dicot	Rs = Reproduction by seeds
M = Monocot	Rv = Reproduction by vegetative means

3.7.1.1 Weed density

In each plot, narrow and broad leaved weeds were counted from two randomly selected area of 0.25 m^2 using 0.5 m x 0.5 m quadrate at 30 and 60 DAS. Weed count was expressed as number m^{-2}. The mean data were subjected to square root transformation $\sqrt{(x+0.5)}$ to normalize their distribution (Gomez and Gomez, 1984).

3.7.1.2 Weed dry matter

The weeds under 0.25 m^2 area were removed at 30, 60 DAS and at harvest and classified as broad-leaved weeds and narrow-leaved weeds. These were dried at 65^0C temperature in oven till a constant weight was obtained which was expressed as weed dry matter. The dry matter was then computed in terms of g m^{-2}.

3.7.1.3 Uptake of N, P, K and S by weeds

The dry matter of weeds at harvest was ground and analysed for N, P, K and S contents as detailed for plant analysis. Nutrient N, P, K and S uptake by weeds at harvest were computed by following formula and expressed in terms of kg ha^{-1}.

$$\text{Nutrient uptake by weeds (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in weeds (\%) x Weed dry matter (kg ha}^{-1}\text{)}}{100}$$

3.7.1.4 Weed control efficiency

Weed control efficiency was calculated at harvest using the following formula (Mani *et al*., 1968).

$$\text{WCE} = \frac{\text{X} - \text{Y}}{\text{X}}$$

Where,

WCE = Weed control efficiency

X = Weed dry matter in weedy check

Y = Weed dry mater in treated plot

3.7.2 Crop studies

3.7.2.1 Maize

1. Visual phytotoxicity scoring

The herbicide toxicity on crop stand and growth was recorded at 15, 25, 35 and 45 DAS by rating it in the scale of 0 to 10. While zero rating represented no injury to crop plants, 10 represented complete destruction (Table 3.7).

Table 3.7: Description of visual rating scale in terms of toxicity on crop (Rao, 2000)

Effect	Rating	Crop description
None	0	No injury, normal
Slight	1	Slight stunting, injury or discoloration
	2	Some stand loss, stunting or discoloration
	3	Injury more pronounced but not persistent
Moderate	4	Moderate injury, recovery possible
	5	Injury more persistent, recovery doubtful
	6	Near severe injury, no recovery possible
Severe	7	Severe injury, stand loss
	8	Almost destroyed, a few plants surviving
	9	Very few plants alive
Complete	10	Complete destruction

2. Growth Characters

(i) Plant Population

The numbers of plants were counted after thinning in five randomly selected one metre row length in each experimental unit at 30 DAS and at harvest. These were averaged and number of plants m^{-2} was worked out.

(ii) Plant height

Five plants were selected randomly, tagged in each plot and height was measured from ground level to tip of tassel at 30 DAS and at harvest by metre scale at maturity and average height was worked out in centimetres.

(iii) Dry matter accumulation

The periodic changes in dry matter accumulation plant^{-1} were recorded at 30, 60 DAS and at harvest by uprooting five randomly selected plants from each plot. These samples (i.e. above ground plant parts) were placed in perforated paper bags followed by sun drying for two days and finally kept in oven at 65^{o}C till a constant weight was noted. Dry matter accumulation plant^{-1} was computed for each treatment at each stage and it was expressed as g plant^{-1}.

(iv) Growth indices (CGR and RGR)

Crop growth rate (CGR) and relative growth rate (RGR) were computed between 30-60 and 60-90 DAS by the following formulae as given by Redford (1967).

$$\text{(i) CGR (g m}^{-2}\text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

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

Where,

W_1 and W_2 are dry matter at time t_1 and t_2, respectively. ‘p’ represents the ground area.

(v) Days to 50% silking

In each experimental unit, number of days required for 50% silking *i.e.* silk appearance in 50% cobs were recorded.

3. Yield attributes

(i) Number of cobs plant^{-1}

The number of cobs in each net plot area in each experimental unit were counted at harvesting and divided by plant population of same net area recorded at harvest and the value expressed in cobs plant^{-1}.

(ii) Number of grains cob^{-1}

Five cobs were randomly selected from the total cobs of sample plants and after shelling and cleaning, total number of grains was counted. Thereafter, average was worked out and expressed in number of grains cob^{-1}.

(iii) Weight of grains plant^{-1}

The grains obtained from five randomly selected cobs were weighed. The weight was multiplied with number of cobs plant^{-1} to obtain weight of grains plant^{-1} and expressed in gram.

(iv) Test weight

A composite sample of grains was taken from the final produce in each plot at the time of threshing. Thereafter; 1000 grains were counted, weighed and expressed in gram.

(v) Shelling per cent

Shelling per cent was computed empirically for five cobs selected at random by the use of following formula.

$$\text{Shelling (\%)} = \frac{\text{Weight of grain}}{\text{Weight of cob}} \times 100$$

4. Yield and harvest index

(i) Grain yield

After shelling and winnowing, grain yield of each net plot was weighed separately and recorded as grain yield in kg plot^{-1}. Thereafter, it was converted to kg ha^{-1}.

(ii) Stover yield

After picking cobs, the sun dried stover from net plot was weighed for individual plot and final stover yield was expressed in kg ha^{-1}.

(iii) Biological yield

Biological yield was determined by weighing and summing up completely dried produce of individual net plot and computed in terms of kg ha^{-1}.

(iv) Harvest index (HI)

The harvest index was calculated by dividing the economic yield (grain yield) by biological yield and expressed as percentage (Donald and Hamblin, 1976).

$$\text{HI (\%)} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

3.7.3 Plant analysis

(i) Chlorophyll content 30 and 60 DAS

Fresh leaf sample were collected at 30 and 60 DAS from crop, and immediately were taken to lab, washed with distil water and dried with blotting paper. A sample of 100 mg was taken from each experimental unit in mortar and pestle. The sample was ground well with 80 per cent acetone and filtered into a 25 ml volumetric flask the volume was raised and absorbance was recorded. The Chlorophyll content was estimated as per standard procedure (Arnon, 1949).

$$\text{Chlorophyll content (mg g}^{-1}\text{ f. w.)} = \left(\frac{20.2(A645) + 8.02(A663)}{a \times 1000 \times W}\right) X\ V$$

Where,

a = length of light path in cell (1 cm)
V = volume of extract in ml
W = fresh weight of leaf sample in g

(ii) Nutrient content

For estimation of nitrogen, phosphorus, potassium and sulphur contents, representative plant samples were collected at harvest, oven dried and ground to fine powder and nutrient contents in grain and straw were estimated as per the method given in Table 3.8.

Table 3.8: Methods for determination of nutrient content

Nutrient	Method of analysis	Reference
Nitrogen	Nesseler’s reagent colorimetric method	Lindner (1944)
Phosphorus	Ammonium vanadomolybdo phosphoric acid yellow colour method	Richards (1968)
Potassium	Flame photometer method	Jackson (1973)
Sulphur	Barium chloride gelatin reagent turbidimetric method	Tabatabai and Bremner (1970)

(iii) Nutrient uptake

The uptake of nutrient by grain and stover at harvest were calculated by using following formula:

$$\text{Nutrient uptake by Grain/stover (kg ha}^{-1}) = \frac{\text{Nutrient content in grain/stover (\%) X Grain/stover yield (kg ha}^{-1})}{}$$

Total nutrient uptake by the crop was computed by summing up the uptake by both grain and stover.

(iv) Protein content

The grain samples collected at harvest from produce of each experimental unit were oven dried at 65°C to a constant weight and ground in laboratory mill. These samples were subjected to chemical analysis for determination of protein content through Lowry protein assay method (Lowry *et al.,* 1951).

3.7.4 Soil analysis

(i) Available nutrient

Random soil samples were drawn at two different locations from each plot up to 15 cm depth after harvest of the crop. These were air dried and pass through 2 mm sieve and analysed for pH, EC, organic carbon and available N, P, K and S as per method furnished in Table 3.2.

(ii) Soil enzyme

Soil samples were collected at harvest and were analyzed for Dehydrogenase (Casida *et al.,* 1964), Phosphatase (Tabatabai and Bremner, 1969) and Urease (Douglas and Bremner, 1970) activity.

3.7.5 Economic evaluation

In order to evaluate the economic viability of different treatments and to ascertain the most remunerative treatment, economics of different treatment combinations were worked out in terms of net return ₹ ha^{-1} and B:C ratio. The expenses incurred on cultivation operations from preparatory tillage to harvesting and threshing including cost of input *viz.*, seed, fertilizer, plant protection chemicals applied to each treatment were computed and cost of cultivation was worked out.

3.7.5.1 **Net return**

To find out the more profitable treatment, economics of different treatments were worked out in terms of net return (₹ ha^{-1}) on the basis of the prevailing market rates so that the most remunerative treatment could be recommended.

3.7.5.2 Benefit:Cost ratio

Benefit:Cost (B:C) ratio for each treatment was calculated to ascertain economic viability of the treatment using the following formula.

$$\text{Benefit: Cost ratio} = \frac{\text{Net return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3.8 RESIDUAL STUDIES ON SUCCEEDING WHEAT

3.8.1 Weed studies

A list of dominant weed species found in experiment presented in Table 3.9.

Table 3.9: Weed flora of experimental field

S.No.	Botanical name	English name	Family	Growth habit
1.	*Amaranthus viridis* L.	Slender amaranth	Amaranthaceae	AB
2.	*Anagallis arvensis* L.	Scarlet	Primulaceae	AB
3.	*Avena fatua* L.	Wild oat	Poaceae	AG
4.	*Chenopodium album* L.	Common lambsquarters	Chenopodiaceae	AB
5.	*Chenopodium murale* L.	Goosefoot	Chenopodiaceae	AB
6.	*Convolvulus arvensis* L.	Field bindweed	Convolvulaceae	PB
7.	*Malva parviflora* L.	Mallow	Malvaceae	AB
8.	*Melilotus indica* (L.) All.	Senjimethi	Leguminosae	AB
9.	*Phalaris minor* Retz.	Little seed canary grass	Poaceae	AG

A = Annual, B = Broad-leaved, G = Grassy, P = Perennial

3.8.1.1 Weed density

Weed density was recorded at 30 DAS in each plot at two spots selected randomly using 0.25 m^2 quadrate. Separate counts were recorded for grassy and broadleaf weeds and expressed as number m^{-2}. The data obtained were subjected to square root transformation $\sqrt{(x+0.5)}$.

3.8.1.2 Weed dry matter

The weeds collected from 0.25 m^2 area in each plot, were first dried and then kept in an electric oven at 65^{o}C to obtain constant weight expressed as g m^{-2}.

3.8.2 Crop studies

3.8.2.1 Visual phytotoxicity scoring

Many weed control treatments affect crop growth as various growth parameters are dependable and accurate measure of treatment effect. Hence, growth and yield characters *viz.,* seedling emergence, plant height, plant dry weight, tillers per meter row length, panicle length, grain per panicle, crop yield and quality were used to judge the residual effect. Crop phytotoxicity was observed based on frequent usual observation at 30 DAS using the scale 0-10 (Table 3.7).

3.8.2.2 Growth parameters

(i) Plant height

The height of five randomly tagged plants from each plot was measured from the ground to the tip of the main shoot at 30 DAS whereas; at harvest the height was measured to the tip of the upper spikelet of main ear (excluding awns). The average plant height was calculated and expressed in cm**.**

(ii) Dry matter accumulation

Dry matter accumulation was recorded at 30 DAS and at harvest by removing five plants from each plot randomly. The samples were sun dried for three days and finally dried in an oven at 65^{o}C and weighed. The dry matter so obtained was expressed as g m^{-2}.

3.8.2.3 Yield parameters

(i) Number of tillers

The total numbers of tillers per meter row were recorded from five randomly selected plots in each plot.

(ii) Spike length

The length of ten spike collected randomly from each plot was measured and the average was expressed as length of spike in cm.

(iii) Grain spike^{-1}

Grain numbers of ten randomly selected ear of plant from central rows were recorded at crop maturity for determining the average number of grain ear^{-1}.

(iv) 1000 - Grain weight

Wheat grain sample were drawn from produce of each plot while weighing the plot yield. For this, 1000 grain were selected randomly and weighed on an electric top pan balance.

3.8.2.4 Yield and harvest index

(i) Grain yield

After threshing and winnowing grain yield plot^{-1} was weighed, which was expressed as kg ha^{-1}.

(ii) Straw yield

The straw yield was calculated by subtracting the corresponding grain yield from the biological yield and expressed in terms of yield as kg ha^{-1}.

(iii) Biological yield

The unthreshed produce from net plot area after through sun drying was weighed for recoding the biological yield and expressed in terms of yield in kg ha^{-1}.

(iv) Harvest index (HI)

It was expressed as the ratio of grain yield to above ground total biological yield and expressed as (Donald and Hamblin, 1976).

3.9 STATISTICAL ANALYSIS

3.9.1 Analysis of variance and test of significance

All the data were subjected to statistical analysis by adopting appropriate method of analysis of variance as described by Cocharan and Cox (1967). The homogeneous results of two years were subjected to pooled analysis to establish the trend of treatments applied as per Gomez and Gomez (1984). Wherever, the ‘F’ values were found significant at 5 per cent level of probability, the critical difference (CD) values were computed for making comparison among the treatment means.

3.9.2 Correlation and regression studies

Correlation studies were carried out with a view to determine interrelationship between various characters as described by Panse and Sukhatme (1985). Regression equation for the characters indicating significantly correlation were also worked out and presented at appropriate places.

Table 3.2: Physico-chemical properties of soil of the experimental field

	Properties	Value		Method of analysis	Reference
		2015	2016		
A.	**Mechanical composition**				
	Sand (%)	38.28	37.20	Hydrometer method	Bouyoucos, 1962
	Silt (%)	27.65	28.84		
	Clay (%)	34.07	33.80		
	Textural class	Clay loam	Clay loam	Triangular diagram	Brady, 1983
B.	**Physical properties**				
	Bulk density (Mg m^{-3})	1.47	1.48	Core sampler method	Piper, 1950
	Particle density (Mg m^{-3})	2.64	2.63	Pycnometer method	Black, 1965
	Porosity (%)	44.32	43.73		Black, 1965
C.	**Chemical properties**				
	Organic carbon (%)	0.77	0.75	Rapid titration method	Walkley and Black, 1947
	Available nitrogen (N kg ha^{-1})	285.0	279.61	Alkaline $KMnO_4$ method	Subbiah and Asija, 1956
	Available phosphorus (P_2O_5 kg ha^{-1})	20.42	19.27	Olsen's method	Olsen *et al*., 1954
	Available potassium (K_2O kg ha^{-1})	324.16	318.15	Flame photometer method	Richards, 1968
	Available sulphur (mg kg^{-1})	9.30	8.90	Turbidimetric method	Chesnin and Yien, 1950
	Available zinc (mg kg^{-1})	2.40	2.45	DTPA-TEA method	Lindsay and Norvell (1978)
	EC (dSm^{-1} at 25 ^{o}C)	1.03	1.01	Conductivity bridge method	Richards, 1968
	Soil pH (1:2.5 soil water suspension)	8.1	8.0	pH meter	Richards, 1968

Table 3.1(a): Weekly average of meteorological data during experimental period for *kharif* 2015 and 2016

Standard Weeks	Period	Atmospheric temperature (^0C)				Relative humidity (%)				Sunshine (h day^{-1})		Rain fall (mm)		Evaporation (mm day^{-1})	
		2015		2016		2015		2016							
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	2015	2016	2015	2016	2015	2016
27	02-08 July	32.9	25.7	35.0	23.6	72.4	51.1	90.0	42.0	6.0	4.7	0.0	1.8	8.7	5.8
28	09-15 July	34.5	26.2	31.0	23.8	69.7	44.2	86.7	70.9	5.0	1.8	0.0	91.6	9.2	4.8
29	16-22July	32.7	24.9	29.9	24.3	79.3	61.1	78.0	67.1	2.4	3.6	45.2	5.4	5.2	4.9
30	23-29 July	34.6	23.0	30.8	23.6	92.1	88.1	89.7	74.0	0.2	3.2	217.8	157.6	2.8	4.2
31	30-05 Aug	28.5	23.3	27.9	23.3	80.3	69.7	92.0	83.0	2.4	0.5	29.2	124.2	4.1	2.3
32	06-12 Aug	31.6	24.3	26.8	23.5	84.0	68.6	95.0	89.0	4.0	0.5	43.4	104.5	4.3	1.0
33	13-19 Aug	29.8	23.6	30.0	23.0	89.1	73.8	83.6	65.6	2.0	6.3	62.0	0.6	2.9	5.5
34	20-26 Aug	30.3	23.7	27.6	23.2	79.4	61.3	91.1	78.9	6.5	1.2	0.0	61.2	4.7	2.1
35	27-02 Sept	31.6	22.8	30.4	23.5	82.9	57.0	89.4	71.1	7.7	3.8	0.0	14.4	4.9	3.2
36	03-09 Sept	32.0	20.6	29.9	22.2	76.3	48.6	78.7	57.7	8.3	7.4	0.0	0.0	5.0	4.9
37	10-16 Sept	34.8	22.5	31.7	21.8	70.1	41.9	78.1	49.3	7.7	8.1	0.0	0.0	5.4	3.7
38	17- 23 Sept	30.5	23.5	34.6	23.3	86.1	72.1	81.6	47.6	3.2	5.7	44.6	3.4	3.5	4.6
39	24- 30 Sept	31.9	19.3	35.3	22.1	77.6	41.3	74.0	42.7	8.9	8.1	0.0	0.0	4.9	5.5
40	01–07 Oct	35.4	17.7	31.7	23.2	62.6	24.0	88.4	65.1	8.3	3.3	0.0	62.4	5.1	3.2
41	08-14 Oct	35.1	17.4	32.0	19.5	64.7	27.0	81.1	41.9	9.1	8.1	0.0	0.0	5.0	4.7
42	15-21 Oct	35.9	18.9	32.4	17.9	63.0	24.3	72.0	30.4	7.9	7.5	0.0	0.0	4.6	4.4
43	22- 28 Oct	34.3	16.6	30.8	15.7	64.7	24.7	76.0	32.0	8.1	8.8	0.0	0.0	4.7	4.5
44	29- 04 Nov	29.1	16.1	30.6	12.5	75.6	35.4	75.7	30.4	8.2	8.2	0.0	0.0	4.4	3.6

Source: Agromet observatory, Instructional Farm, Department of Agronomy, RCA, Udaipur (Rajasthan)

Table 3.1(b): Weekly average of meteorological data during experimental period for *rabi* 2015-16 and 2016-17

Standard Weeks	Period	Atmospheric temperature (^{0}C)				Relative humidity (%)				Sunshine (h day^{-1})		Rain fall (mm)		Evaporation (mm day^{-1})	
		2015-16		2016-17		2015-16		2016-17							
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
45	05- 11 Nov	32.1	15.1	30.9	11.7	61.9	27.3	71.6	24.1	8.0	8.4	0.0	0.0	3.8	3.4
46	12-18 Nov	32.2	14.4	29.3	10.3	60.7	28.6	84.6	34.6	8.5	8.6	0.0	0.0	4.1	2.6
47	19-25 Nov	29.5	11.9	30.5	10.7	70.6	33.3	82.4	23.1	8.4	9.0	0.0	0.0	2.9	2.6
48	26-02 Dec	28.3	11.7	30.3	10.6	64.6	34.6	80.4	24.7	5.9	9.0	0.0	0.0	3.4	2.9
49	03-09 Dec	29.3	8.6	27.7	8.9	70.3	35.0	88.7	27.6	8.4	8.6	0.0	0.0	3.0	2.6
50	10-16 Dec	25.0	6.8	28.3	10.4	69.6	33.6	90.1	32.4	8.0	8.7	0.0	0.0	2.1	2.7
51	17-23 Dec	23.8	4.0	27.5	9.8	77.3	23.6	89.4	29.1	7.4	8.6	0.0	0.0	2.2	2.5
52	24-31 Dec	27.5	6.9	27.6	9.4	78.4	18.6	85.4	24.9	7.4	8.5	0.0	0.0	2.4	2.6
01	01-07 Jan	28.7	9.7	26.2	8.3	83.6	26.0	92.1	37.9	7.2	7.9	0.0	0.0	2.9	2.8
02	08-14 Jan	27.3	8.3	20.9	5.6	83.0	25.3	89.6	38.9	7.5	5.8	0.0	0.0	2.9	2.3
03	15-21 Jan	23.7	8.0	21.8	7.1	83.1	35.0	80.7	43.1	4.9	6.5	0.0	0.0	2.4	2.4
04	22- 28 Jan	25.9	6.0	26.0	10.4	80.1	22.1	91.6	47.0	8.9	5.4	0.0	0.2	3.0	2.6
05	29- 04 Feb	27.7	10.0	27.0	8.6	72.0	27.7	91.6	36.0	8.2	8.7	0.0	0.0	3.6	2.8
06	05–11 Feb	26.6	7.3	25.1	7.2	78.0	19.6	84.1	28.7	9.1	8.4	0.0	0.0	3.8	3.8
07	12-18 Feb	26.0	12.2	27.4	11.0	68.1	27.3	88.0	34.1	8.2	8.0	0.0	0.0	4.5	3.5
08	19-25 Feb	30.5	11.9	30.0	11.1	66.9	18.4	71.4	26.0	7.6	8.8	0.0	0.0	4.4	5.2
09	26- 04 Mar	31.6	11.6	31.4	12.7	67.5	21.0	71.1	26.0	8.9	9.1	0.0	0.0	4.9	5.1
10	05- 11 Mar	31.7	14.1	29.1	12.2	67.6	28.7	73.1	23.7	8.5	7.8	0.0	0.0	5.6	5.0
11	12-18 Mar	30.9	15.1	29.2	10.1	70.0	32.1	63.0	16.9	6.7	8.6	0.0	0.0	6.2	5.5
12	19-25 Mar	34.1	15.7	34.1	15.1	51.7	17.9	73.6	17.4	8.4	8.8	0.0	0.0	7.4	6.3
13	26-01 Apr	35.9	17.9	38.1	18.6	52.6	19.7	46.4	10.9	6.1	9.5	0.0	0.0	6.7	8.9
14	02-08 Apr	36.6	20.0	36.4	19.7	50.6	18.9	46.0	17.3	6.3	9.2	0.0	0.0	8.9	10.3

Source: Agromet observatory, Instructional Farm, Department of Agronomy, RCA, Udaipur (Rajasthan)

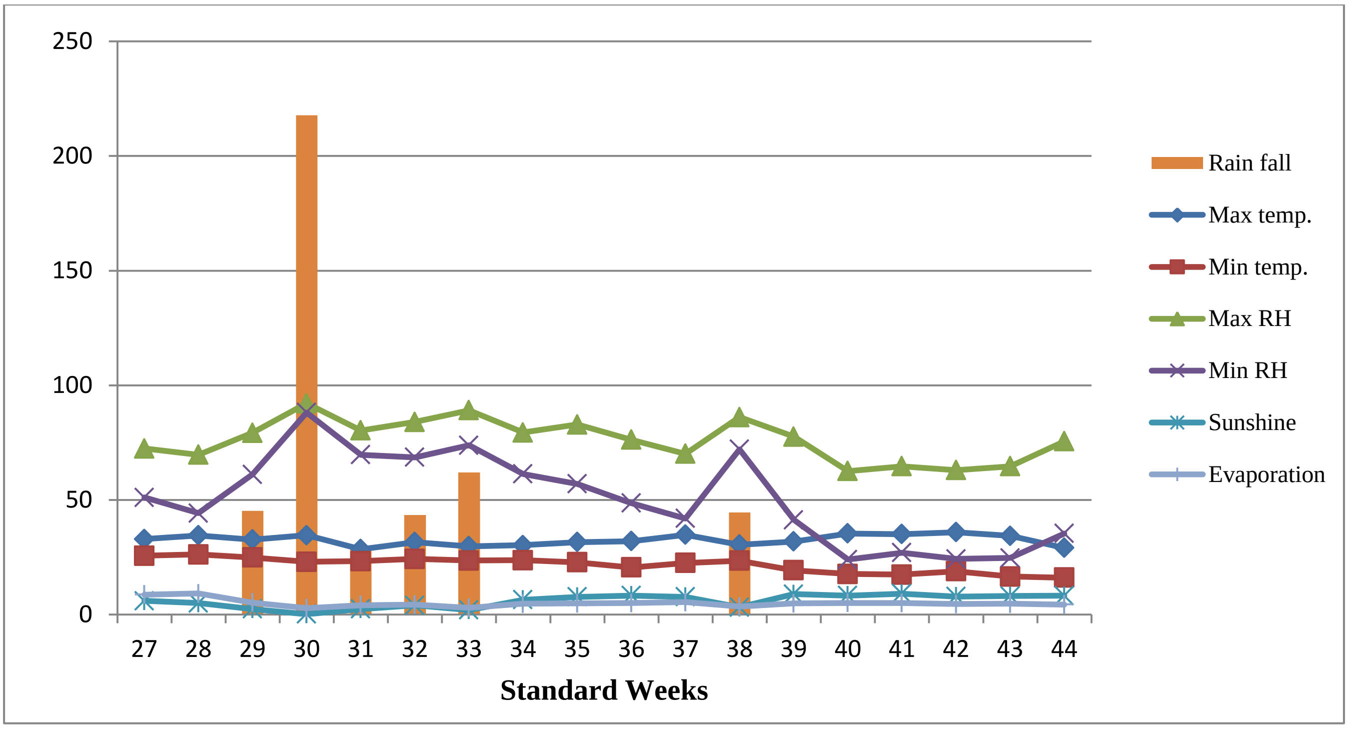


Fig. 3.1 Mean weekly meteorological data during crop growing season *kharif* 2015

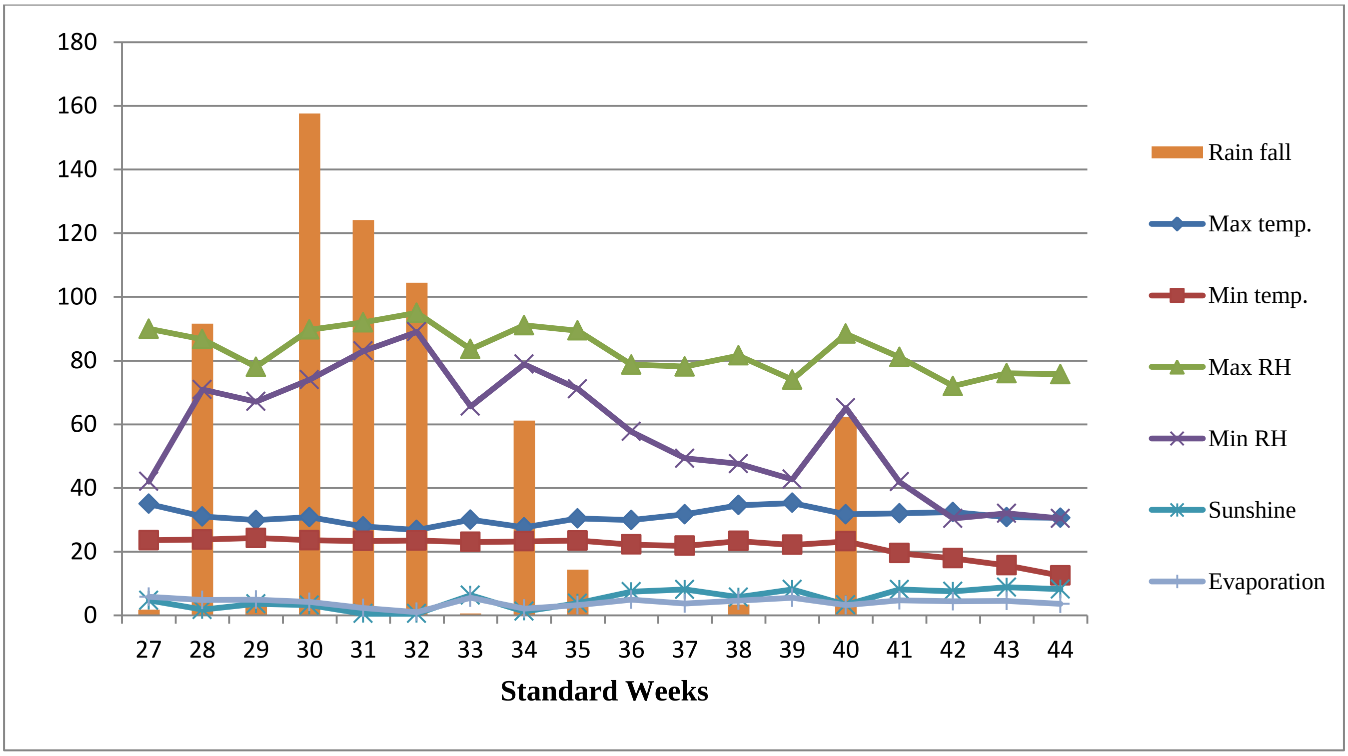
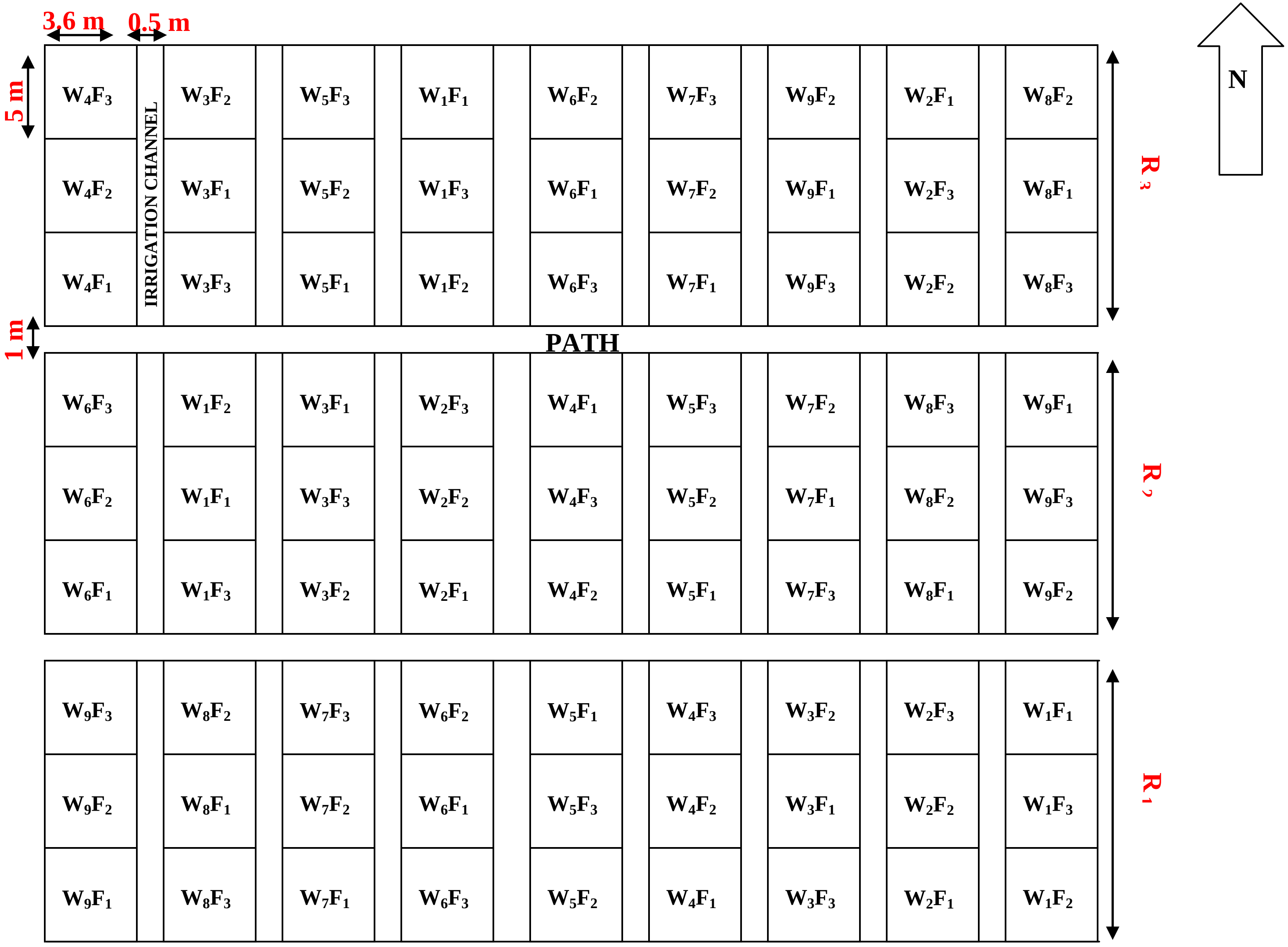


Fig. 3.2 Mean weekly meteorological data during crop growing season *kharif* 2016



(A) Weed management (Main plot)

W_1 = Weedy check
W_2 = Hand weeding at 15 DAS and 35 DAS
W_3 = Tembotrione 0.125 kg ha^{-1} at 20 DAS
W_4 = Alachlor 2.0 kg ha^{-1} as PE *fb* Hand weeding at 35DAS
W_5 = Atrazine 0.5 kg ha^{-1} as PE *fb* Hand weeding at 35DAS
W_6 = Tembotrione 0.125 kg ha^{-1} at 20 DAS *fb* Hand weeding at 35 DAS
W_7= Alachlor 2.0 kg ha^{-1}+Atrazine 0.5 kg ha^{-1} as PE *fb* Hand weeding at 35 DAS
W_8 = Alachlor 2.0 kg ha^{-1} as PE *fb* Tembotrione 0.125 kg ha^{-1} at 20 DAS
W_9 = Atrazine 0.5 kg ha^{-1} as PE *fb* Tembotrione 0.125 kg ha^{-1} at 20 DAS

(B) Nutrient management (Sub plot)

F_1 = NPK
F_2 = NPK+Zn
F_3 = NPKS+Zn

Design	:	Split plot
Total treatments	:	27
Replications	:	3
Gross plot size	:	5.0 m x 3.6 m
Net plot size	:	4.0 m x 2.4 m

Fig 3.3: Plan of Layout

4. EXPERIMENTAL RESULTS

The results of field experiment entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur during two consecutive years of 2015-16 and 2016-17, are presented in this chapter. The data pertaining to effect of different treatments on weeds and crop were statistically analyzed and after evaluating them for the test of significance, only significant effects are described in detail length with the help of suitable tables and graphs. Analysis of variance for these data has been given in the appendices at the end, whereas significant effects at 5 per cent level of probability have been indicated by asterisks.

4.1 WEED STUDIES

4.1.1 Weed density

4.1.1.1 At 30 DAS

The data pertaining to weed density are given in Tables 4.1 (a) to 4.1 (d). It is clarified that hand weeding treatment at 35 DAS was not performed at this stage of observation.

- ***Echinochloa colona***

Weed management: The data explicit that all weed management treatments under test significantly reduced the population of this weed at 30 DAS in comparision to weedy check. While the range of reduction was 78.59 to 68.05 per cent in first year, its extent of reduction was 77.16 to 65.56 per cent in the second year. During both the years of experimentation, the minimum density was observed with application of atrazine *fb* tembotrione. However, in the year 2015 its effect was at par with that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS and alachlor+atrazine *fb* hand weeding. In 2016, its effect was statistically equivalent to that of alachlor *fb* tembotrione and two hand weedings at 15 & 35 DAS.

The pooled data revealed that application of atrazine *fb* tembotrione gave the minimum weed density (1.94 m^{-2}), which was at par with that of alachlor *fb* tembotrione and two hand weedings at 15 & 35 DAS. The reduction in the density of this weed due to atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weeding 15 & 35 DAS and alachlor+atrazine *fb* hand weeding treatments was to the tune of 95.71, 95.35, 95.09 and 94.08 per cent, respectively over weedy check (8.78 m^{-2}).

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit any significant variation in the density of *Echinochloa colona* in both the years as well as on pooled basis over NPK.

- ***Cynodon dactylon***

Weed management: The data pertaining to density of *Cynodon dactylon* at 30 DAS indicated that the plots treated with atrazine *fb* tembotrione recorded minimum densities (2.27 and 2.21 m^{-2}) during both the years which were at par with those of two hand weedings at 15 & 35 DAS and significantly lower than all other treatments.

The pooled results revealed that the plots treated with atrazine *fb* tembotrione recorded minimum density (2.24 m^{-2}). This treatment reduced the density of *Cynodon dactylon* by 62.20 per cent over weedy check (3.52 m^{-2}) and was significantly superior to all other treatments.

Nutrient management: Application of Zn and Zn+S with NPK had no significant effect on density of *Cynodon dactylon* at 30 DAS in both the years of experimentation and on pooled basis over NPK.

- ***Cyperus rotundus***

Weed management: Weed management through two hand weedings resulted in significant reduction in density of *Cyperus rotundus* during both the years of investigation *i.e.,* during 2015 (2.65 m^{-2}) and 2016 (2.65 m^{-2}) over weedy check. The pooled results indicate that application of two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione significantly reduced density of *Cyperus rotundus* by 49.61, 49.07 and 47.69 per cent, respectively over weedy check (3.66 m^{-2}). Further, these treatments were statistically at par in controlling *Cyperus rotundus.*

Nutrient management: Density of *Cyperus rotundus* recorded at 30 DAS was not influenced significantly by Zn and Zn+S with NPK during both the years of experimentation as well as on pooled basis over NPK.

- ***Dinebra retroflexa***

Weed management: All the weed management practices under test were significantly superior over weedy check in term of reduction in density of *Dinebra retroflexa* at 30 DAS. The data indicate that application of atrazine *fb* tembotrione caused maximum reduction in density of this weed over weedy check during both the years. On pooled basis, application of atrazine *fb* tembotrione was significantly controlled the density of this weed by 83.24 per cent over weedy check (5.53 m^{-2}).

Nutrient management: The density of *Dinebra retroflexa* recorded at 30 DAS was not influenced significantly by Zn and Zn+S with NPK during both the years of experimentation as well as on pooled basis over NPK alone.

- ***Brachiaria reptans***

Weed management: The density of *Brachiaria reptans* was significantly affected by weed management during both the years of investigation. Results reveal that two hand weedings at 15 & 35 DAS recorded minimum density of this weed during both the years as well as on pooled basis (2.20 m^{-2}). However, in the year 2015 its effect was at par with that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS and alachlor+atrazine *fb* hand weeding. While in 2016, its effect was statistically similar to that of alachlor *fb* tembotrione and two hand weedings at 15 & 35 DAS. On pooled basis, application of two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione significantly reduced the density of *Bracheria reptans* by 67.36, 66.32 and 64.45 per cent, respectively over weedy check (3.72 m^{-2}). Further, these treatments were statistically at par in controlling the density of this weed.

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit any significant variation in the density of *Brachiaria reptans* in both the years as well as on pooled basis.

- ***Amaranthus viridis***

Weed management: All the weed management treatments reduced the density of *Amaranthus viridis* at 30 DAS by significant margin ranging from 63.04 to 46.58 and 61.88 to 35.32 per cent during 2015 and 2016, respectively over weedy check. Weed management through atrazine *fb* tembotrione brought maximum reduction in this weed during both the years of experimentation. However, in the year 2015, its effect was at par with that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS and alachlor+atrazine *fb* hand weeding. While in the second year, its effect was statistically equivalent to that of alachlor *fb* tembotrione and two hand weedings at 15 & 35 DAS.

On pooled basis, application of atrazine *fb* tembotrione was significantly superior over rest of treatments and controlled the density of this weed by 62.5 per cent over weedy check (3.93 m^{-2}).

Nutrient management: Application of Zn and Zn+S with NPK did not cause significant variation in the density of *Amaranthus viridis* during either of years and on pooled basis at 30 DAS over NPK.

- ***Digera arvensis***

Weed management: All the weed management practices under test were significantly superior over weedy check in term of reduction in density of *Digera arvensis* at 30 DAS. Application of atrazine *fb* tembotrione significantly reduced the density of *Digera arvensis* during both the years of study over weedy check, tembotrione, alachlor *fb* hand weeding, atrazine *fb* hand weeding and tembotrione *fb* hand weeding. On pooled basis application of atrazine *fb* tembotrione significantly reduced the density of this weed by 60.63 per cent whereas two hand weedings reduced the density by 59.69 per cent over weedy check (3.49 m^{-2}). Further, both these treatments were statistically at par in controlling the density of this weed.

Nutrient management: Application of Zn and Zn+S with NPK did not influence the density of *Digera arvensis* in both the years as well as on pooled basis over NPK.

- ***Trianthema portulacastrum***

Weed management: The count of *Trianthema portulacastrum* was significantly affected by weed management treatments. Data revealed that alachlor+atrazine *fb* hand weeding recorded minimum weed population during the first year as well as on pooled basis while during second year, it was minimum with application of atrazine *fb* tembotrione. On pooled basis, application of alachlor+atrazine *fb* hand weeding was significantly superior over rest of treatments and controlled the density of this weed by 74.98 per cent over weedy check (6.14 m^{-2}).

Nutrient management: A perusal of data indicate that application of Zn and Zn+S with NPK failed to cause significant variation in density of *Trianthema portulacastrum* during both the years and on pooled basis over NPK.

- ***Commelina benghalensis***

Weed management: The density of *Commelina benghalensis* was minimum during both the years of study with weed management practice of two hand weedings at 15 & 35 DAS and its effect was at par with that of alachlor *fb* tembotrione, atrazine *fb* tembotrione and alachlor+atrazine *fb* hand weeding. The trend of pooled results was same as that of individual year's result except that reduction in *Commelina benghalensis* density by alachlor+atrazine *fb* hand weeding was not at par with the two hand weedings at 15 & 35 DAS. Pooled results indicate that application of two hand weeding, atrazine *fb* tembotrione and alachlor *fb* tembotrione were statistically at par in controlling the density of *Commelina benghalensis* and these treatments significantly reduced the density of this weed by 79.38, 78.85 and 78.35 per cent, respectively over weedy check (4.96 m^{-2}).

Nutrient management: Irrespective of years and on pooled basis, weed density of *Commelina benghalensis* was not affected by the application of Zn and Zn+S with NPK over NPK.

- **Narrow-leaved weeds**

Weed management: All the weed management practices under test were significantly superior to weedy check in term of reduction in density of narrow-leaved weeds at 30 DAS. The control of narrow-leaved weeds through application of atrazine *fb* tembotrione was maximum at 30 DAS over weedy check during both the years. On pooled basis, application of atrazine *fb* tembotrione was significantly superior over rest of treatments and controlled the density of narrow-leaved weeds by 83.49 per cent over weedy check (12.06 m^{-2}).

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit any significant variation in the density of narrow-leaved weeds over NPK.

- **Broad-leaved weeds**

Weed management: The data explicit that all weed management treatments under test significantly reduced the population of broad-leaved weeds at 30 DAS over weedy check. While the range of reduction was 70.80 to 60.44 in first year, its extent was 70.85 to 55.37 per cent in the second year. The pooled data indicate that application of atrazine *fb* tembotrione and two hand weedings brought about significant reduction in density of broad-leaved weeds at 30 DAS by 70.83 and 69.51 per cent, respectively over weedy check (9.41 m^{-2}). Further, both these treatments were statistically at par in controlling the density of broad-leaved weeds.

Nutrient management: A perusal of data reveal no significant effect of application of Zn and Zn+S with NPK on broad-leaved weeds density at 30 DAS in both the years as well as on pooled basis over NPK.

- **Total weeds**

Weed management: An examination of data reveal that application of atrazine *fb* tembotrione showed maximum reduction in the total weed density at 30 DAS over weedy check during both the years of study. However, in the year 2015 its effect was at par with that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS and alachlor+atrazine *fb* hand weeding. While in the second year, its effect was statistically equivalent to that of two hand weedings at 15 & 35 DAS. The pooled data reveal that total weeds count was minimum with application of atrazine *fb* tembotrione (7.08 m^{-2}) and it was significantly superior over rest of treatments and controlled the density of total weeds by 78.7 per cent over weedy check (15.28 m^{-2}).

Nutrient management: No significant effect on total weed density was observed due to application of Zn and Zn+S with NPK during both the years and on pooled basis over NPK.

4.1.1.2 At 60 DAS

Data related to weed density at 60 DAS are presented in Tables 4.2 (a) to 4.2 (d).

- ***Echinochloa colona***

Weed management: All the weed management practices reduced the density of *Echinochloa colona* by significant margin ranging from 94.48 to 89.19 and 94.15 to 88.98 per cent during 2015 and 2016, respectively over weedy check. During both the years of study, maximum control of this weed was observed with application of atrazine *fb* tembotrione, which proved significantly superior over weedy check, tembotrione, alachlor *fb* hand weeding, atrazine *fb* hand weeding and tembotrione *fb* hand weeding. The pooled results indicate that application of atrazine *fb* tembotrione recorded 94.32 per cent reduction in density of this weed which was significantly superior over weedy check (9.55 m^{-2}) and at par with alachlor *fb* tembotrione. Application of alachlor *fb* tembotrione was found next in order of superiority that resulted in 93.88 per cent decrease in the density.

Nutrient management: Application of Zn and Zn+S with NPK had no significant effect on density of *Echinochloa colona* at 60 DAS during both the years of experimentation over NPK.

- ***Cynodon dactylon***

Weed management: The data explicit that density of *Cynodon dactylon* was significantly reduced by all weed management treatments in comparison to weedy check during both the years of experimentation. On pooled basis, maximum reduction in density of *Cynodon dactylon* was recorded with application of atrazine *fb* tembotrione (2.80 m^{-2}) which was statistically at par with two hand weeding, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding in reducing the density of this weed and these treatments significantly reduced the density of this weed by 63.45, 62.20, 60.76 and 60.16 per cent, respectively over weedy check (4.53 m^{-2}).

Nutrient management: A perusal of data indicates that application of Zn and Zn+S with NPK failed to cause significant variation in density of *Cynodon dactylon* during both the years and on pooled basis over NPK.

- ***Cyperus rotundus***

Weed management: Weed management treatments recorded significantly lower density of *Cyperus rotundus* compared to weedy check during both the years. On pooled basis, application of two hand weedings significantly reduced the density of this weed by 56.25 per cent compared to weedy check (4.44 m^{-2}) which was significantly superior over rest of the treatments except atrazine *fb* tembotrione and alachlor *fb* tembotrione, which accounted for 55.31 and 53.29 per cent decline in density of this weed, respectively over weedy check.

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit any significant variation in the population of *Cyperus rotundus* in both the years and on pooled basis over NPK.

- ***Dinebra retroflexa***

Weed management: During both the years of study and on pooled basis, application of atrazine *fb* tembotrione with minimum density of *Dinebra retroflexa* at 60 DAS proved significantly superior over weedy check. On pooled basis, two hand weedings and alachlor *fb* tembotrione were next best treatment in this regard, however, these were at par with atrazine *fb* tembotrione. The density of *Dinebra retroflexa* was reduced by 83.67, 82.11 and 81.89 per cent by application of atrazine *fb* tembotrione, two hand weeding and alachlor *fb* tembotrione, respectively compared to weedy check (6.22 m^{-2}).

Nutrient management: Application of Zn and Zn+S with NPK did not influence the density of *Dinebra retroflexa* during both the years as well as on pooled basis over NPK.

- ***Brachiaria reptans***

Weed management: Density of *Brachiaria reptans* was significantly reduced due to weed management during both the years of study as well as on pooled basis. Maximum reduction in density of this weed (2.61 m^{-2}) was obtained with two hand weedings at 15 and 35 DAS which recorded 68.13 per cent reduction in density of this weed which was significantly superior over weedy check (4.52 m^{-2}). Application of atrazine *fb* tembotrione and alachlor *fb* tembotrione were found next in order of superiority with 67.73 and 66.53 per cent decrease in the density of *Brachiaria reptans*. Further, these treatments were statistically at par in terms of controlling the density of this weed.

Nutrient management: Application of Zn and Zn+S with NPK had no significant effect on density of *Brachiaria reptans* at 60 DAS during both the years of experimentation over NPK.

- ***Amaranthus viridis***

Weed management: It is evident from the data that application of atrazine *fb* tembotrione gave maximum reduction in the density of *Amaranthus viridis* during both the years of experimentation. The pooled result revealed that atrazine *fb* tembotrione gave maximum reduction in the density (2.81 m^{-2}) of this weed. Application of two hand weedings and alachlor *fb* tembotrione were the next treatments in order of superiority which were statistically at par with atrazine *fb* tembotrione and both these treatments resulted in significantly lower density of *Amaranthus viridis* over rest of treatments. Application of atrazine *fb* tembotrione, two hand weeding and alachlor *fb* tembotrione were responsible for 65.11, 63.88 and 63.17 per cent reduction in the density of *Amaranthus viridis*, respectively over weedy check (4.65 m^{-2}).

Nutrient management: The density of *Amaranthus viridis* recorded at 60 DAS was not influenced significantly by application of Zn and Zn+S with NPK during both the years of experimentation as well as on pooled basis over NPK.

- ***Digera arvensis***

Weed management: All the weed management treatments reduced density of *Digera arvensis* significantly as against weedy check during both the years of experimentation as well as on pooled basis at 60 DAS. Two hand weeding 15 and 35 DAS resulted in minimum density of this weed followed by application of atrazine *fb* tembotrione, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding. On pooled basis, minimum density of this weed was observed with two hand weeding (2.62 m^{-2}) which was at par with atrazine *fb* tembotrione and alachlor *fb* tembotrione and gave 69.97, 68.16 and 67.18 per cent control of *Digera arvensis*, respectively over weedy check (4.68 m^{-2}).

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit any significant variation in the density of *Digera arvensis* during both the years and on pooled basis over NPK.

- ***Trianthema portulacastrum***

Weed management: The density of *Trianthema portulacastrum* tended to reduce significantly with different treatments compared to weedy check. The lowest population was observed under application of atrazine *fb* tembotrione during both the years. However, in the year 2015 its effect was at par with that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS, alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding. While in the second year, its effect was statistically equivalent to that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS and alachlor+atrazine *fb* hand weeding. The pooled data show 69.22, 68.56, 68.47 and 67.81 per cent reduction in density of this weed with the application of atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weeding and alachlor+atrazine *fb* hand weeding, respectively over weedy check (6.76 m^{-2}). Further, these treatments were statistically at par with each other in terms of controlling the density of this weed.

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit any significant variation in the density of *Trianthema portulacastrum* in both the years and on pooled basis over NPK.

- ***Commelina benghalensis***

Weed management: Compared to weedy check, all weed management practices resulted in significant reduction in density of *Commelina benghalensis* over weedy check. During both the years of study as well on pooled basis maximum reduction of this weed was observed with application of two hand weedings at 15 and 35 DAS. Pooled data further indicate that application of two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione reduced the density of this weed by 77.29, 76.18 and 75.78 per cent, respectively over weedy check (5.56 m^{-2}). Further, these treatments were statistically at par with each other in terms of controlling the density of this weed.

Nutrient management: A perusal of data indicate that application of Zn and Zn+S with NPK failed to cause significant variation in density of *Commelina benghalensis* during both the years and on pooled basis over NPK.

- **Narrow-leaved weeds**

Weed management: During both the years of study, hand weeding and application of herbicides proved significantly superior over weedy check in reducing density of narrow-leaved weeds. During both the years as well as on pooled basis, the minimum weed count was recorded under application of atrazine *fb* tembotrione. Pooled analysis further indicate that atrazine *fb* tembotrione and two hand weedings resulted in 82.05 and 81.38 per cent, respectively reduction in the narrow-leaved weeds density over weedy check (13.74 m^{-2}). Further, both these treatments were statistically at par in terms of controlling the density of narrow-leaved weeds.

Nutrient management: No significant effect on narrow-leaved weeds density was observed due to application of Zn and Zn+S with NPK during both the years of experiment and on pooled basis over NPK.

- **Broad-leaved weeds**

Weed management: An examination of data revealed that all weed management practices resulted in significant reduction in density of broad-leaved weeds compared to weedy check during both the years of study. Maximum reduction of broad-leaved weeds observed under application of two hand weedings. On pooled basis, application of two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione reduced the density of broad-leaved weeds by 70.20, 70.09 and 69.21 per cent, respectively over weedy check (10.90 m^{-2}). Further, these treatments were statistically at par with each other in terms of controlling the density of broad-leaved weeds.

Nutrient management: Irrespective of years and on pooled basis, density of broad-leaved weeds was not affected by the application of Zn and Zn+S with NPK over NPK.

- **Total weeds**

Weed management: It is evident from the data that application of herbicides and hand weeding significantly controlled total weeds density compared to weedy check during both the years of investigation. During both the years as well as on pooled basis, effect of atrazine *fb* tembotrione was statistically superior over all other treatments. On pooled basis, atrazine *fb* tembotrione was at par with two hand weedings and alachlor *fb* tembotrione. Weed management practices like application of atrazine *fb* tembotrione, two hand weedings and alachlor *fb* tembotrione recorded 77.43, 77.06 and 76.36 per cent reduction, respectively in the density of total weeds over weedy check (17.52 m^{-2}).

Nutrient management: A perusal of data indicate that application of Zn and Zn+S with NPK failed to cause significant variation in density of total weeds during both the years and on pooled basis over NPK.

4.1.2 Weed dry matter

4.1.2.1 At 30 DAS

The data related to weed dry matter are presented in Table 4.3 (a). Application of hand weeding at 35 DAS was not followed at this stage.

- **Narrow-leaved weeds**

Weed management: The data explicit that application of atrazine *fb* tembotrione brought about maximum reduction in weed dry matter of narrow-leaved weeds during both the years of study. However, during first year i.e., 2015 its effect was at par with that of alachlor *fb* tembotrione, two hand weedings at 15 & 35 DAS and alachlor+ atrazine *fb* hand weeding. While in the second year, its effect was statistically equivalent to that of alachlor *fb* tembotrione and two hand weedings at 15 & 35 DAS. The pooled results indicate that application of atrazine *fb* tembotrione, two hand weedings and alachlor *fb* tembotrione significantly reduced dry matter of narrow-leaved weeds by 69.99, 69.70 and 69.30 per cent, respectively over weedy check (52.02 g m^{-2}). Further, these treatments were statistically at par in terms of reducing the weed dry matter.

Nutrient management: The dry matter of narrow-leaved weeds was not influenced by application of Zn and Zn+S with NPK during both the years of study as well as on pooled basis over NPK.

- **Broad-leaved weeds**

Weed management: It is evident from the data that application of atrazine *fb* tembotrione recorded maximum reduction in dry matter of broad-leaved weeds over weedy check during both the years. The pooled analysis of results revealed that application of atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding were statistically at par with each other and reduced the dry matter of broad-leaved weeds by 80.16, 79.76, 79.49 and 78.99 per cent, respectively over weedy check (44.36 g m^{-2}).

Nutrient management: Application of Zn and Zn+S with NPK did not significantly influence the dry matter of broad-leaved weeds at 30 DAS during both the years as well as on pooled basis over NPK.

- **Total weeds**

Weed management: The data explicit that weed control through atrazine *fb* tembotrione recorded maximum reduction in dry matter of total weeds at 30 DAS over weedy check during both the years. The pooled data further indicate that application of atrazine *fb* tembotrione, two hand weedings at 15 and 35 DAS, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding were statistically at par with each other and significantly reduced the weed dry matter by 74.66, 74.21, 74.12 and 73.19 per cent, respectively over weedy check (96.39 g m^{-2}).

Nutrient management: A perusal of data indicates that application of Zn and Zn+S with NPK failed to cause significant variation in dry matter of weeds during both the years and on pooled basis at 30 DAS over NPK.

4.1.2.2 At 60 DAS

The data related to weed dry matter at 60 DAS are given in Table 4.3 (b).

- **Narrow-leaved weeds**

Weed management: Different herbicides and manual weeding under study brought about significant reduction in dry matter of narrow-leaved weeds at 60 DAS over weedy check. Application of atrazine *fb* tembotrione recorded lowest dry matter of narrow-leaved weeds and its effect was superior over rest of the treatments during two years of study. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings at 15 and 35 DAS brought about 65.17, 64.91 and 64.47 per cent reduction in dry matter of narrow-leaved weeds, respectively over weedy check (173.0 g m^{-2}). Further, these treatments were statistically at par in terms of reducing the weed dry matter at 60 DAS.

Nutrient management: Application of NPKS+Zn significantly increased the weed dry matter over NPK during both the years of study. The pooled results indicate an increase of 1.68 per cent in weed dry matter under NPKS+Zn over NPK (80.21 g m^{-2}).

- **Broad-leaved weeds**

Weed management: The results indicate that maximum reduction in dry matter of broad-leaved weeds was recorded under application of atrazine *fb* tembotrione and this treatment was significantly superior over rest of the treatments during both the years of experimentation. On pooled basis, atrazine *fb* tembotrione and alachlor *fb* tembotrione recorded significant reduction in dry matter of broad-leaved weeds by 64.10 and 63.75 per cent, respectively over weedy check (173.0 g m^{-2}). Further, both these treatments were statistically at par with each other in terms of reducing the weed dry matter at 60 DAS.

Nutrient management: The data explicit that on pooled basis, application of NPKS+Zn significantly enhanced weed dry matter by 1.71 per cent over NPK application (70.78 g m^{-2}).

- **Total weeds**

Weed management: Application of atrazine *fb* tembotrione resulted in minimum weed dry matter during both the years of experimentation. The pooled data indicate 64.67 and 64.36 per cent reduction in total weed dry matter through application of atrazine *fb* tembotrione and alachlor *fb* tembotrione, respectively in comparison to weedy check (327.02 g m^{-2}). Further, both these treatments were statistically at par with each other in terms of reducing the total weed dry matter at 60 DAS.

Nutrient management: Application of NPKS+Zn significantly increased the weed dry matter over NPK during both the years of study. The pooled data show 1.70 per cent increase in weed dry matter by applying NPKS+Zn over NPK (150.99 g m^{-2}).

4.1.2.3 At harvest

The data on weed dry matter at harvest are given in Table 4.3 (c).

- **Narrow-leaved weeds**

Weed management: The data explicit that all weed management treatments under test significantly reduced the dry matter of narrow-leaved weeds at harvest in comparision to weedy check. During two years of experimentation, the minimum weed dry matter was observed with application of atrazine *fb* tembotrione. On the basis of pooled data, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings resulted in 71.64, 71.36 and 71.32 per cent decrease, respectively in narrow-leaved weed dry matter at harvest over weedy check (243.08 g m^{-2}). Further, these treatments were statistically at par with each other in terms of reducing the narrow-leaved weeds dry matter at harvest.

Nutrient management: Application of NPKS+Zn significantly increased the weed dry matter over NPK during both the years of study. The pooled results indicate an increase of 1.23 per cent in weed dry matter under NPKS+Zn over NPK (102.4 g m^{-2}).

- **Broad-leaved weeds**

Weed management: Application of herbicides and hand weeding brought about significant reduction in dry matter of broad-leaved weeds at harvest during both the years of experimentation. Atrazine *fb* tembotrione recorded minimum weed dry matter and was significantly superior to rest of the treatments during both the years of experimentation. The pooled data revealed that atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings at 15 and 35 DAS resulted in 72.50, 72.45 72.08 per cent reduction in weed dry matter, respectively over weedy check (235.03 g m^{-2}). Further, these treatments were statistically at par in terms of reducing the broad-leaved weeds dry matter at harvest.

Nutrient management: The data explicit that on pooled basis, application of NPKS+Zn significantly enhanced weed dry matter by 1.66 per cent over NPK (97.99 g m^{-2}).

- **Total weeds**

Weed management: Different herbicides and manual weeding brought about significant reduction in dry matter of total weeds at harvest. During both the years atrazine *fb* tembotrione recorded the lowest dry matter of total weeds over rest of the treatments. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings significantly reduced the dry matter of total weeds by 72.06, 71.89 and 71.69 per cent, respectively over weedy check (478.11 g m^{-2}). Further, these treatments were statistically at par with each other in reducing total weed dry matter at harvest.

Nutrient management: Application of NPKS+Zn significantly increased the weed dry matter over NPK during both the years of study. The pooled data show 1.44 per cent increase in weed dry matter by applying NPKS+Zn over NPK (200.43 g m^{-2}).

4.1.3 Weed control efficiency (WCE)

The data on weed control efficiency at harvest are presented in Table 4.4.

- **Narrow-leaved weeds**

Weed management: Weed control efficiency at harvest based on weed dry matter varied to a great extent under the influence of various weed control treatments. On pooled basis, atrazine *fb* tembotrione proved very effective in controlling weeds and recorded the maximum weedy control efficiency (71.61 per cent) of narrow-leaved weeds. Alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding were next in order of superiority with 71.32, 71.27 and 69.11 per cent weed control efficiency, respectively.

- **Broad-leaved weeds**

Weed management: All the weed management practices resulted in increased weed control efficiency during both the years of experimentation. WCE of broad-leaved weeds was highest under atrazine *fb* tembotrione (72.51 per cent) followed by application of alachlor *fb* tembotrione (72.45 per cent), two hand weedings (72.05 per cent) and alachlor+atrazine *fb* hand weeding (70.12 per cent) on pooled basis. Further, lowest weed control efficiency was observed with tembotrione alone (50.56 per cent).

- **Total weeds**

Weed management: A perusal of data indicates that various weed management practices differed in their ability to control weeds. The highest weed control efficiency was achieved with atrazine *fb* tembotrione during both the years of investigation and on pooled basis. The pooled data show weed control efficiency of 72.07, 71.88, 71.67 and 69.61 per cent under atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding, respectively. Further, atrazine *fb* hand weeding (63.89 per cent) and alachlor *fb* hand weeding (62.17 per cent) proved better than tembotrione *fb* hand weeding (58.57 per cent) and tembotrione alone (50.61 per cent) in this regard.

4.1.4 Nutrient content in weeds

The data related to nutrient content in weeds at harvest are given in Table 4.5.

Weed management: The data explicit that there was no significant effect of weed management practices on N, P, K and S content in weeds during both the years and on pooled basis.

Nutrient management: Application of Zn and Zn+S with NPK failed to exhibit significant effect on N, P, K content in weeds during both the years of experimentation while increase in S content with NPKS+Zn was significant over NPK and NPK+Zn.

4.1.5 Nutrient uptake by weeds

The data related to nutrient uptake by weeds at harvest are presented in Table 4.6 (a) and 4.6 (b).

4.1.5.1 N uptake

Weed management: All weed management treatments were significantly superior to weedy check in reducing N uptake by weeds. On pooled basis, the lowest N uptake by weeds was observed with application of atrazine *fb* tembotrione. The next best treatments in this order were application of alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding. However, all these treatments were statistically at par with each other. Further analysis of data reveal that atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding significantly reduced N uptake by weeds by 72.14, 71.94, 71.72 and 69.65 per cent, respectively over weedy check (63.22 kg ha^{-1}).

Nutrient management: Application of Zn and Zn+S with NPK had no significant impact on N uptake by weeds in both the years of study as well as on pooled basis.

4.1.5.2 P uptake

Weed management: The pooled data indicate that different weed management treatments significantly reduced P uptake by weeds over unweeded control. The maximum reduction in P uptake by weeds was achieved with atrazine *fb* tembotrione which was significantly higher over rest of the treatments. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding reduced P uptake by total weeds by 73.23, 72.89, 72.81 and 71.21 per cent, respectively over weedy check (11.88 kg ha^{-1}). Further, these treatments were statistically at par with each other in reducing P uptake by weeds at harvest.

Nutrient management: Application of Zn and Zn+S with NPK had no significant impact on P uptake by weeds in both the years of study as well as on pooled basis.

4.1.5.3 K uptake

Weed management: In comparison to weedy check, all the weed management treatments significantly reduced the K uptake by weeds at harvest during both the years of study. The minimum K uptake was recorded under atrazine *fb* tembotrione which was followed by alachlor *fb* tembotrione, two hand weeding and alachlor+ atrazine *fb* hand weeding. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding decreased K uptake by weeds by 72.31, 72.08, 71.93 and 69.67 per cent, respectively over weedy check (78.80 kg ha^{-1}). Further, these treatments were statistically at par with each other in reducing K uptake by weeds at harvest.

Nutrient management: Application of Zn and Zn+S with NPK had no significant impact on K uptake by weeds in both the years of study as well as on pooled basis.

4.1.5.4 S uptake

Weed management: Weed management treatments caused marked variation in S uptake by weeds at harvest. On pooled basis, atrazine *fb* tembotrione recorded minimum S uptake by weeds, however, its effect remained at par with alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding. On pooled basis, atrazine *fb* tembotrione, two hand weedings, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding significantly reduced the S uptake by weeds by 73.26, 73.14, 72.91 and 71.26 per cent, respectively over weedy check (8.49 kg ha^{-1}).

Nutrient management: Application of NPKS+Zn significantly increased S uptake by weeds during both the years of study. The pooled results indicate an increase of 12.5 per cent in S uptake by weeds under NPKS+Zn over NPK (3.36 kg ha^{-1}).

4.2 CROP STUDIES

4.2.1 Plant population at 30 DAS and harvest

The data related to plant population are presented in Table 4.7.

Weed management: All the weed management treatments did not differ significantly in their effect on plant population at 30 DAS and at harvest during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management also had no significant effect on plant population at 30 DAS and at harvest during both the years of experimentation.

4.2.2 Growth Studies

The data pertaining to growth parameters are given in Tables 4.8 to 4.11.

4.2.2.1 Plant height

The data related to plant height are presented in Table 4.8.

4.2.2.1.1 At 30 DAS

Weed management: An assessment of data revealed that the height of QPM at 30 DAS significantly increased by different weed management practices over weedy check. The maximum plant height was recorded under atrazine *fb* tembotrione which was at par with alachlor *fb* tembotrione during the second year of experimentation and on pooled basis but during the first year atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings, alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding were at par with each other but attained significantly more plant height than tembotrione alone, tembotrione *fb* hand weeding and weedy check. On pooled basis, an increase of 36.14 and 33.91 per cent was observed in plant height through atrazine *fb* tembotrione and alachlor *fb* tembotrione, respectively, over weedy check (56.89 cm). Further, both these treatments were statistically at par for plant height at 30 DAS.

Nutrient management: Application of NPKS+Zn significantly increased the height of QPM during both the years of study. The pooled results indicate an increase of 4.46 and 2.63 per cent in height under NPKS+Zn and NPK+Zn, respectively, over NPK (68.36 cm).

4.2.2.1.2 At harvest

Weed management: An assessment of data revealed that the height of QPM at harvest significantly increased by different weed management practices over that of weedy check. The maximum plant height was recorded under atrazine *fb* tembotrione which was at par with alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding during both the years of experimentation. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings were at par with each other but significantly differed with alachlor+atrazine *fb* hand weeding attaining plant height at harvest. On pooled basis, an increase of 32.13, 31.12 and 29.74 per cent was observed in plant height through atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings, respectively over weedy check (159.40 cm).

Nutrient management: Application of NPKS+Zn significantly increased the height of QPM during both the years of study. The pooled results indicate an increase of 1.47 and 3.33 per cent in height with NPKS+Zn and NPK+Zn (190.59 cm), respectively over NPK (187.83 cm).

4.2.2.2 Dry matter accumulation

The data related to dry matter accumulation at 30 and 60 DAS and at harvest are presented in Table 4.9 and depicted in Fig 4.3.

4.2.2.2.1 At 30 DAS

Weed management: Application of atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings were at par with each other but significantly increased dry matter of QPM at 30 DAS over rest of treatments during both the years of experimentation as well as on pooled basis. On pooled basis, an increase of 178.53, 169.02 and 168.92 per cent was observed in dry matter through atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings, respectively over weedy check (9.78 g).

Nutrient management: The data explicit that on pooled basis, application of NPKS+Zn significantly enhanced dry matter accumulation by 7.49 per cent over NPK (20.95 g).

4.2.2.2.2 At 60 DAS

Weed management: It is apparent from the data that dry matter of QPM significantly increased by different weed management practices over weedy check. The maximum dry matter was recorded under atrazine *fb* tembotrione which was at par with alachlor *fb* tembotrione and two hand weedings during the second year of experimentation and on pooled basis but during the first year, atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding were at par with each other and significantly better than rest of treatments crop dry matter accumulation. On pooled basis, application of atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings recorded 50.51, 44.36 and 44.0 per cent higher dry matter accumulation, respectively over weedy check (55.16 g).

Nutrient management: An increase of 5.27, 3.22 and 4.22 per cent was recorded in dry matter accumulation of QPM when the nutrients' level was raised from NPK to NPKS+Zn during both the years and on pooled basis, respectively.

4.2.2.2.3 At harvest

Weed management: All the weed control treatments *viz.* hand weeding, application of herbicides alone and in combination with hand weeding significantly increased the dry matter of QPM over weedy check during both the years of experimentation. The pooled data indicate that alachlor *fb* tembotrione recorded maximum dry matter which was significantly higher by 7.36, 8.07, 9.89, 12.88 and 42.88 per cent over atrazine *fb* hand weeding, alachlor *fb* hand weeding, tembotrione *fb* hand weeding, tembotrione alone and weedy check (139.84 g), respectively. However, atrazine *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding were statistically at par with alachlor *fb* tembotrione in this respect. Further analysis of data revealed that atrazine *fb* hand weeding, alachlor *fb* hand weeding, tembotrione *fb* hand weeding, and tembotrione alone but differed non-significantly with each other recorded significantly higher dry matter than weedy check.

Nutrient management: The pooled data show 6.11 and 2.21 per cent increase in dry matter accumulation by applying NPKS+Zn and NPK+Zn, respectively, over NPK (178.13 g). Application of NPKS+Zn was also significantly better than NPK+Zn on pooled basis.

4.2.2.3 Crop growth rate

The data related to crop growth rate between 30-60 DAS and 60 DAS - at harvest are presented in Table 4.10.

4.2.2.3.1 Between 30-60 DAS

Weed management: All the weed management treatments did not differ significantly in their effect on crop growth rate between 30-60 DAS during both the years of experimentation as well as on pooled basis.

Nutrient management: Application of Zn and Zn+S with NPK also had no significant effect on crop growth rate between 30-60 DAS during both the years of experimentation.

4.2.2.3.2 Between 60 DAS - At harvest

Weed management: All the weed management treatments did not differ significantly in their effect on crop growth rate between 60 DAS - at harvest during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management did not influence this parameter during both the years of experimentation.

4.2.2.4 Relative growth rate

The data pertaining to relative growth rate between 30-60 DAS and 60 DAS - at harvest are presented in Table 4.11.

4.2.2.4.1 Between 30-60 DAS

Weed management: All the weed management treatments did not differ significantly in their effect on relative growth rate between 30-60 DAS during both the years of experimentation as well as on pooled basis.

Nutrient management: Application of Zn and Zn+S with NPK also had no significant effect on relative growth rate between 30-60 DAS during both the years of experimentation.

4.2.2.4.2 Between 60 DAS – At harvest

Weed management: All the weed management treatments did not differ significantly in their effect on relative growth rate between 60 DAS - at harvest during both the years of experimentation as well as on pooled basis.

Nutrient management: Application of Zn and Zn+S with NPK also had no significant effect on relative growth rate between 60 DAS - at harvest during both the years of experimentation.

4.2.2.5 Days to 50% silking

The data related to days to 50% silking are presented in Table 4.13.

Weed management: All the weed management treatments did not differ significantly in their effect on days to 50% silking during both the years of experimentation as well as on pooled basis.

Nutrient management: Application of Zn and Zn+S with NPK also had no significant effect on days to 50% silking during both the years of experimentation.

4.2.3 Visual phytotoxicity scoring:

The data on effect of the treatments on visual phytotoxicity are given in Table 4.12.

4.2.3.1 At 15 DAS

During both the years of investigation, visual phytotoxicity scoring revealed that at 15 DAS, atrazine and alachlor caused slight stunting, injury and discolouration of maize plants.

4.2.3.2 At 25 DAS

During the first year of study it was observed that at this stage, the injury was more pronounced but not persistent for both atrazine and alachlor herbicides. The visual scoring at 25 DAS also indicated some plant stand loss, stunting or discoloration of maize plants under the effect of tembotrione while plant stand in the plots treated with alachlor *fb* tembotrione and atrazine *fb* tembotrione showed more pronounced injury but not persistent. After that during the second-year atrazine and alachlor treated plots showed slight injury only while atrazine and alachlor *fb* tembotrione caused some stand loss, stunting or discoloration of maize plants.

4.2.3.3 At 35 DAS

During both the years of experimentation, at this stage the phytotoxicity caused by these two herbicides i.e., atrazine and alachlor was not visible i.e. the plants recovered and there was no injury and normal plant stand. However, at 35 DAS, the phytotoxicity caused by tembotrione was moderate and more persistent to maize plants putting the plants under doubtful recovery zone.

4.2.3.4 At 45 DAS

During both the successive years of evaluation the visual phytotoxicity scoring of the field at 45 DAS revealed that the crop plants under all these treatments had recovered and that no symptoms of phytotoxicity were seen at this stage.

4.2.4 Yield attributes

The data related to yield attributes of QPM are presented in Tables 4.13 and 4.14.

4.2.4.1 Number of grains cob^{-1}

Weed management: A critical examination of data revealed that all weed control treatments had a significant effect on the number of grains cob^{-1}. The highest number of grains cob^{-1} was recorded under atrazine *fb* tembotrione which was significantly higher over rest of the treatments except over two hand weedings and alachlor *fb* tembotrione in the second year and on pooled basis, whereas, in the first year two hand weeding treatment also differed significantly. The pooled analysis revealed that application of atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings, alachlor+atrazine *fb* hand weeding brought about 39.15, 36.91, 35.76 and 23.74 per cent increase, respectively in grains cob^{-1} over weedy check (264.38).

Nutrient management: Application of Zn and Zn+S with NPK increased the number of grains cob^{-1} over NPK during both the years. On pooled basis, a significant increase of 2.51 and 1.35 per cent was registered in number of grains cob^{-1} by application of NPKS+Zn over NPK and NPK+Zn, respectively. However, NPK and NPK+Zn didn't bring about any significant effect in number of grains cob^{-1}.

4.2.4.2 Weight of grains

Weed management: A perusal of data revealed that all weed control treatments significantly increased weight of grains over weedy check during both the years. On pooled basis, the maximum weight of grains was recorded under atrazine *fb* tembotrione which was at par with alachlor *fb* tembotrione but significantly superior over rest of the treatments. Further, application of alachlor *fb* tembotrione and two hand weedings were also found statistically at par with each other in terms of weight of grains but significantly higher over rest of the treatments.

Nutrient management: During first year and on pooled basis, application of NPKS+Zn brought about significant increase in weight of grains over NPK. However, the nutrient management did not influence weight of grains significantly during the second year of experimentation.

4.2.4.3 Number of cobs plant^{-1}

Weed management: All the weed management treatments did not differ significantly in their effect on number of cobs plant^{-1} during both the years of experimentation as well as on pooled basis.

Nutrient management: Application of Zn and Zn+S with NPK also had no significant effect on number of cobs plant^{-1} during both the years of experimentation.

4.2.4.4 Test weight

Weed management: Application of herbicides either single or in combinations and hand weeding registered a significant enhancement in test weight during both the years of investigation. Atrazine *fb* tembotrione recorded the maximum test weight during both the years of study. Further, application of alachlor *fb* tembotrione and two hand weedings were at par with each other and significantly superior over rest of the treatments. On pooled basis, the per cent increase in test weight due to atrazine *fb* tembotrione, alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding was 37.14, 33.87, 32.33 and 27.17, respectively over weedy check (154.61 g).

Nutrient management: The data explicit that on pooled basis, application of NPKS+Zn significantly enhanced test weight over NPK+Zn and NPK. However, both these treatments NPK and NPK+Zn differed non-significantly with each other in this regard.

4.2.4.5 Shelling per cent

Weed management: A perusal of data reveal the significance of weed management treatment during both the years and on pooled basis. On pooled basis, maximum shelling per cent (76.58 %) was recorded under atrazine *fb* tembotrione which was statistically at par with alachlor *fb* tembotrione and two hand weedings and significantly superior over rest of the treatments. Further, application of alachlor+atrazine *fb* hand weeding was significant over alachlor *fb* hand weeding and atrazine *fb* hand weeding and both these treatments were statistically at par with each other.

Nutrient management: The data explicit that on pooled basis, application of NPKS+Zn significantly enhanced shelling per cent over NPK. Further, both the treatments NPKS+Zn and NPK+Zn differed non-significantly with each other in this regard.

4.2.5 Yield and harvest index

The data related to yield and harvest index are presented in Table 4.15.

4.2.5.1 Grain yield

Weed management: An insight of the data of both the years elucidates that the grain yield of QPM was significantly enhanced by controlling the weeds through different weed management practices. Atrazine *fb* tembotrione achieved maximum grain yield (4516 kg ha^{-1}) followed by two hand weeding, alachlor *fb* tembotrione, alachlor+ atrazine *fb* hand weeding and atrazine *fb* hand weeding. However, these treatments were statistically at par with each other. The range of yield enhancement was 53.8 to 71.8 per cent over weedy check due to different weed control treatments. On pooled basis, increase in grain yield by atrazine *fb* tembotrione, two hand weedings, alachlor *fb* tembotrione, alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding were 71.8, 71.2, 71.1, 64.2 and 63.2 per cent, respectively over weedy check (2628 kg ha^{-1}).

Nutrient management: It is evident from data that across the years increasing the nutrient from NPK to NPK+Zn and NPK+Zn to NPKS+Zn resulted in significantly higher grain yield of QPM. By all these nutrient managements NPKS+Zn resulted in highest grain yield. The pooled results show 7.5 and 3.2 per cent increase in grain yield by applying NPKS+Zn and NPK+Zn, respectively over NPK (3976 kg ha^{-1}).

4.2.5.2 Stover yield

Weed management: Application of herbicides alone, in combination with hand weeding and their sequential application resulted in significantly higher stover yield over weedy check during both the years as well as in pooled analysis. On pooled basis, atrazine *fb* tembotrione gave the highest stover yield of QPM (7459 kg ha^{-1}) followed by alachlor *fb* tembotrione, two hand weedings, alachlor+ atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding and these treatments were at par with each other, but significantly superior over rest of the treatments. The improvement in stover yield with application of atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings was to the extent of 59.8, 59.5 and 57.5 per cent, respectively over weedy check (4669 kg ha^{-1}). Further, application of alachlor+ atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding recorded significantly increased the stover yield by 54.7, 53.4 and 52.8 per cent, respectively over weedy check. Application of tembotrione *fb* hand weeding proved significantly higher over weedy check but was statistically at par with tembotrione alone in terms of stover yield.

Nutrient management: Following the pattern of grain yield, stover yield also increased significantly with application of Zn and Zn+S over NPK alone. The pooled results indicate 7.2 and 1.9 per cent increase in stover yield with the application of NPKS+Zn and NPK+Zn over NPK (6743 kg ha^{-1}), respectively. However, application of NPK+Zn was statistically at par with NPK in this regard.

4.2.5.3 Biological yield

Weed management: The biological yield of QPM also followed the same trend that was found in grain and stover yield with different weed management practices. Pooled data indicate that atrazine *fb* tembotrione recorded significantly higher biological yield (11976 kg ha^{-1}) which was higher by 5.87, 7.16, 8.35 and 64.12 per cent over alachlor *fb* hand weeding, tembotrione *fb* hand weeding, tembotrione alone and weedy check (7297 kg ha^{-1}), respectively. However, alachlor *fb* tembotrione, two hand weedings, alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding performed equally with atrazine *fb* tembotrione and produced significantly higher biological yield over aforesaid treatments.

Nutrient management: Application of NPK with Zn and Zn+S significantly increased biological yield during both the years of study over NPK. On pooled basis, application of NPKS+Zn and NPK+Zn recorded significantly higher biological yield by 7.3 and 2.4 per cent, respectively over NPK (10719 kg ha^{-1}).

4.2.5.4 Harvest index

Weed management: All the weed management treatments did not differ significantly in their effect on harvest index during both the years of experimentation as well as on pooled basis.

Nutrient management: The nutrient management did not influence harvest index significantly during both the years of experimentation.

4.2.6 Quality analysis

The data pertaining to quality analysis are given in Table 4.16.

4.3.1 Protein content in grain

Weed management: Application of herbicides either single or in combination and hand weeding registered a significant improvement in the protein content of QPM over weedy check during the course of study. Maximum protein content was recorded under two hand weedings which was at par with application of atrazine *fb* tembotrione and alachlor *fb* tembotrione and significantly superior over rest of treatments. Examination of data further revealed that effect of atrazine *fb* hand weeding, alachlor *fb* hand weeding, tembotrione *fb* hand weeding and tembotrione alone were superior to weedy check, but at par to each other. On pooled basis, two hand weedings (12.04 %), atrazine *fb* tembotrione (11.90 %), alachlor *fb* tembotrione (11.77 %) and alachlor+atrazine *fb* hand weeding (11.53 %) recorded significantly higher protein content in comparison to weedy check (10.46 %) and rest of other treatments.

Nutrient management: It is manifested from data that application of S was significantly effective in improving protein content of QPM during both of the years and on pooled basis. The pooled data indicate that application of NPKS+Zn (11.41 %) significantly enhanced protein content over NPK (11.15 %). However, protein content (11.27 %) with application of NPK+Zn was at par with NPKS+Zn and NPK.

4.3 BIOCHEMICAL ANALYSIS

4.3.1 Chlorophyll content

The data related to chlorophlyll content at 30 and 60 DAS are presented in Table 4.16.

4.3.1.1 At 30 DAS

Weed management: A perusal of data reveal that all weed management treatments significantly increased chlorophyll content of QPM at 30 DAS compared to weedy check during both the years of study. On pooled basis, two hand weedings and atrazine *fb* tembotrione significantly increased chlorophyll content by 16.45 and 14.04

per cent, respectively over weedy check (1.617 mg g^{-1}). Further, both these treatments were statistically at par with each other in this regard.

Nutrient management: It is clear from the data that enhancing nutrients up to NPKS+Zn was significantly effective in improving chlorophyll content at 30 DAS during either of the years as well as on pooled basis. On pooled basis, chlorophyll content with application of NPKS+Zn increased significantly by 4.13 per cent over NPK.

4.3.1.2 At 60 DAS

Weed management: A critical analysis of data pertaining to chlorophyll content at 60 DAS of QPM showed significant variation amongst different weed control treatments across the years compared to weedy check. On pooled basis, maximum chlorophyll content was obtained with atrazine *fb* tembotrione but it was statistically at par with two hand weeding, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding and significantly higher over rest of the treatments. Further atrazine *fb* tembotrione, two hand weedings, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding significantly increased chlorophyll content by 9.94, 9.54, 9.02 and 7.99 per cent, respectively over weedy check (1.740 mg g^{-1}).

Nutrient management: It is evident from data that across the years increasing the nutrient from NPK to NPKS+Zn resulted in significantly more chlorophyll content at 60 DAS of QPM. The pooled results showed 2.45 per cent improvement in chlorophyll content by applying NPKS+Zn over NPK (1.835 mg g^{-1}).

4.3.2 Nutrient content at harvest

The data related to nutrient content in grain and stover are presented in Tables 4.17 (a) and 4.17 (b).

4.3.2.1 N, P, K and S content in grain

4.3.2.1.1 N content

Weed management: All the weed management treatments significantly increased the N content in grain during both the years as well as on pooled basis compared to weedy check. The maximum N content in grain was observed with two hand weedings and it was at par with atrazine *fb* tembotrione, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding on pooled basis. Two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione significantly increased the pooled mean N content by 15.05, 13.74 and 12.43 per cent, respectively over weedy check.

Nutrient management: Application of NPKS+Zn significantly increased the pooled mean N content in grain by 2.35 per cent over NPK. However, NPK and NPK+Zn did not differ significantly with each other.

4.3.2.1.2 P content

Weed management: All the weed management treatments significantly increased P content in grain during both the years as well as on pooled basis compared to weedy check. The maximum P content in grain was observed with atrazine *fb* tembotrione and it was statistically at par with alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding on pooled basis. Atrazine *fb* tembotrione significantly increased the pooled mean P content by 52.83 per cent over weedy check.

Nutrient management: Application of NPKS+Zn significantly increased the P content in grain by 1.56 per cent over NPK. However, NPK and NPK+Zn did not differ significantly with each other.

4.3.2.1.3 K content

Weed management: All the weed management treatments significantly increased the K content in grain during both the years as well as on pooled basis compared to weedy check. On pooled basis the maximum K content in grain was observed with atrazine *fb* tembotrione and it was statistically at par with two hand weeding. On pooled basis, atrazine *fb* tembotrione and two hand weedings significantly increased K content by 12.59 and 10.26 per cent, respectively over weedy check.

Nutrient management: Different nutrient management treatments differed significantly for K content in grain. On pooled basis, NPKS+Zn significantly increased the K content in grain by 1.33 per cent over NPK.

4.3.2.1.4 S content

Weed management: All the weed management treatments significantly increased the S content in grain during both the years as well as on pooled basis compared to weedy check. The maximum S content in grain was observed with atrazine *fb* tembotrione and it was statistically at par with two hand weeding and alachlor *fb* tembotrione on pooled basis. Atrazine *fb* tembotrione significantly increased the pooled mean S content by 15.59 per cent over weedy check.

Nutrient management: Different nutrient management treatments differed significantly for S content in grain. On pooled basis, NPKS+Zn significantly increased S content in grain by 5.66 per cent over NPK.

4.3.2.2 N, P, K and S content in stover

4.3.2.2.1 N content

Weed management: A perusal of data revealed that all treatments increased N content in stover significantly in either of the years as well as on pooled basis over weedy check. On pooled basis, maximum N content in stover was obtained with two hand weedings which was statistically at par with atrazine *fb* tembotrione and alachlor *fb* tembotrione and significantly superior over rest of the treatments.

Nutrient management: Nutrient management exerted a significant effect on N content in stover. On pooled basis, maximum N content in stover observed with NPKS+Zn was significantly higher than NPK+Zn and NPK.

4.3.2.2.2 P content

Weed management: A perusal of data reveal that all treatments increased P content in stover significantly in either of the years as well as on pooled basis over weedy check. On pooled basis, maximum P content in stover was noted with atrazine *fb* tembotrione which was statistically at par with two hand weedings, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding but significantly superior over rest of the treatments.

Nutrient management: Nutrient management exerted a significant effect on P content in stover. The maximum P content in stover on pooled basis observed with NPKS+Zn was significantly higher than NPK+Zn and NPK.

4.3.2.2.3 K content

Weed management: An assessment of data revealed that weed management treatments did not differ for K content in stover in both the years and on pooled basis.

Nutrient management: In both the years and on pooled basis K content in stover remained unaffected by different nutrient management treatments.

4.3.2.2.4 S content

Weed management: A perusal of data revealed that all treatments significantly increased the S content in stover in either of the years as well as on pooled basis over weedy check. On pooled basis, maximum S content in stover noted with atrazine *fb* tembotrione was statistically at par with two hand weedings, alachlor *fb* tembotrione and alachlor+atrazine *fb* hand weeding but significantly higher than rest of the treatments.

Nutrient management: Nutrient management treatments showed significant difference in S content in stover. The maximum S content in stover on pooled basis observed with NPKS+Zn was significantly higher than NPK+Zn and NPK.

4.3.3 Nutrient uptake at harvest

The data related to nutrient uptake at harvest by grain and stover is presented in Tables 4.18 (a) and 4.18 (d).

4.3.3.1 N, P, K and S uptake by grain

4.3.3.1.1 N uptake

Weed management: A perusal of data revealed that all weed management treatments significantly increased N uptake by grain over weedy check during both the years of study. Maximum N uptake by grain was recorded with two hand weedings which was statistically at par with atrazine *fb* tembotrione and alachlor *fb* tembotrione. Further, analysis of data revealed that application of alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding were also at par with each other but significantly superior over weedy check in grain N uptake. On pooled basis, application of two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione recorded 95.89, 94.67 and 91.09 per cent higher N uptake by grain, respectively over weedy check.

Nutrient management: Application of S or S+Zn along with NPK increased the N uptake by grain over NPK during both the years. On pooled basis, application of NPK+Zn and NPKS+Zn significantly enhanced N uptake by 19.37 and 22.09 per cent, respectively over NPK. Further increase in grain N uptake with application of NPKS+Zn was also significant over NPK+Zn.

4.3.3.1.2 P uptake

Weed management: Amongst all weed management practices, atrazine *fb* tembotrione resulted in significantly higher P uptake by grain over other treatments except over application of alachlor *fb* tembotrione and two hand weedings in both the experimental years as well as on pooled basis. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings resulted in 162.34, 158.76 and 156.14 per cent increase in P uptake by grain, respectively over weedy check.

Nutrient management: The data explicit that on pooled basis, application of NPKS+Zn and NPK+Zn significantly increased P uptake by 8.99 and 3.81 per cent, respectively over NPK. Increase in grain P uptake with NPKS+Zn was also significantly higher than with NPK+Zn.

4.3.3.1.3 K uptake

Weed management: Various weed management treatments significantly increased K uptake by grain over weedy check during both the years of experimentation. During both the years, maximum K uptake was registered under atrazine *fb* tembotrione and it was at par with two hand weedings and alachlor *fb* tembotrione. Application of alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding were significantly superior over rest of treatments but statistically at par with each other. On pooled basis, application of atrazine *fb* tembotrione, two hand weedings and alachlor *fb* tembotrione increased K uptake by grain to the extent of 93.37, 88.06 and 86.21 per cent, respectively over weedy check.

Nutrient management: An insight of pooled data indicates that significantly higher K uptake was registered with the application of NPKS+Zn (9.09 %) and NPK+Zn (4.10 %) over NPK. Similarly increase in K uptake by grain with NPKS+Zn over NPK+Zn was also significant.

4.3.3.1.4 S uptake

Weed management: All weed control treatments significantly increased S uptake by grain compared to weedy check during both the years of study. Atrazine *fb* tembotrione achieved significantly higher S uptake by grain over other weed management treatments except over two hand weedings and alachlor *fb* tembotrione. Further application of alachlor+atrazine *fb* hand weeding recorded higher S uptake by grain in comparison to rest of other treatments. On pooled basis, atrazine *fb* tembotrione, two hand weeding and alachlor *fb* tembotrione recorded 97.82, 96.03 and 94.36 per cent increase in S uptake by grain, respectively over weedy check.

Nutrient management: It is evident from the data of both the years of study that application of NPKS+Zn resulted in significantly higher S uptake by grain over NPK. The pooled data showed 11.30 and 4.42 per cent increase in S uptake by NPKS+Zn and NPK+Zn, respectively over NPK. Increase in S uptake with application of NPKS+Zn was also significant over NPK+Zn.

4.3.3.2 N, P, K and S uptake by stover

4.3.3.2.1 N uptake

Weed management: On pooled basis, amongst all weed management treatments, maximum N uptake by stover was recorded with two hand weedings and it was at par with atrazine *fb* tembotrione and alachlor *fb* tembotrione but significantly superior over all other treatments. Further, application of alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding resulted in significantly higher N uptake by stover over alachlor *fb* hand weeding, tembotrione *fb* hand weeding, tembotrione alone and weedy check but both were at par with each other in terms of N uptake by stover of QPM.

Nutrient management: The pooled data showed that application of NPKS+Zn and NPK+Zn recorded significant increase in N uptake by stover over NPK. However, application of NPKS+Zn also registered significant increase in N uptake by stover over NPK+Zn.

4.3.3.2.2 P uptake

Weed management: On pooled basis, amongst all weed management treatments, maximum P uptake by stover was recorded under atrazine *fb* tembotrione. However, it was at par with alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding but significantly superior over all other treatments. Further, application of atrazine *fb* hand weeding, alachlor *fb* hand weeding, tembotrione *fb* hand weeding and tembotrione alone also registered significantly higher P uptake over weedy check but were at par with each other in terms of P uptake by stover of QPM.

Nutrient management: The pooled data showed that application of NPKS+Zn recorded significant increase in P uptake by stover over NPK+Zn and NPK. Similarly increase in pooled mean P uptake with NPK+Zn over NPK was also significant.

4.3.3.2.3 K uptake

Weed management: On pooled basis, amongst all weed management treatments, maximum K uptake by stover was recorded under atrazine *fb* tembotrione. However, it was at par with alachlor *fb* tembotrione, two hand weedings, alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding and significantly superior over all other treatments. Further, application of tembotrione *fb* hand weeding and tembotrione alone registered similar but significantly higher K uptake by stover of QPM over weedy check.

Nutrient management: The pooled data showed that application of NPKS+Zn recorded significant increase in K uptake by stover over NPK and NPK+Zn.

4.3.3.2.4 S uptake

Weed management: On pooled basis, amongst all weed management treatments, maximum S uptake by stover was recorded with application of atrazine *fb* tembotrione. However, it was at par with alachlor *fb* tembotrione and two hand weedings and significantly superior over all other treatments. Further, application of alachlor+atrazine *fb* hand weeding resulted in significantly higher S uptake over atrazine *fb* hand weeding, alachlor *fb* hand weeding, tembotrione *fb* hand weeding, tembotrione alone and weedy check whereas these treatments except weedy check were statistically at par with each other in terms of S uptake by stover of QPM.

Nutrient management: The pooled data showed that application of NPKS+Zn recorded significant increase in S uptake by stover over NPK and NPK+Zn. Application of NPK+Zn also registered significantly higher S uptake by stover.

4.3.3.3 Total uptake of N, P, K and S by crop

4.3.3.3.1 Total N uptake

Weed management: The data reveal that total N uptake by crop was significantly increased with weed control measures over weedy check during both the years as well as on pooled basis. On pooled basis, two hand weedings resulted in highest total N uptake closely followed by application of atrazine *fb* tembotrione and alachlor *fb* tembotrione. Critical examination of data further revealed that application of alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding were statistically at par with each other but significantly superior over rest of all treatments. On pooled basis, two hand weedings, atrazine *fb* tembotrione and alachlor *fb* tembotrione enhanced total N uptake by 93.50, 92.78 and 89.72 per cent, respectively over weedy check.

Nutrient management: It is clear from data that during both the years of investigation, application of S or S+Zn along with NPK significantly enhanced total N uptake by crop over NPK. The pooled results indicated increase of 3.93 and 9.76 per cent in total N uptake with the application of NPK+Zn and NPKS+Zn, respectively over NPK. Total N uptake recorded with the application of NPKS+Zn was also statistically more than with NPK+Zn.

4.3.3.3.2 Total P uptake

Weed management: The data reveal that total P uptake by crop was significantly increased through weed control measures over weedy check during both the years as well as on pooled basis. On pooled basis, atrazine *fb* tembotrione resulted in highest total P uptake closely followed by application of alachlor *fb* tembotrione and two hand weedings. Critical examination of data further revealed that application of alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding were at par with each other but significantly superior over rest of all treatments. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings enhanced total P uptake by 121.15, 117.93 and 115.72 per cent, respectively over weedy check.

Nutrient management: During both the years of investigation, application of Zn and Zn+S along with NPK significantly enhanced total P uptake by crop over NPK. The pooled results indicated increase of 3.50 and 9.22 per cent in total P uptake with the application of NPK+Zn and NPKS+Zn, respectively over NPK. Total P uptake recorded with the application of NPKS+Zn was also significantly more than with NPK+Zn.

4.3.3.3.3 Total K uptake

Weed management: The data reveal that total K uptake by crop was significantly increased through weed control measures over weedy check during both the years as well as on pooled basis. On pooled basis, atrazine *fb* tembotrione resulted in highest total K uptake closely followed by application of alachlor *fb* tembotrione, two hand weedings, alachlor+atrazine *fb* hand weeding and atrazine *fb* hand weeding. On pooled basis, atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings enhanced total K uptake by 71.03, 69.51 and 68.09 per cent, respectively over weedy check.

Nutrient management: During both the years of investigation, application of Zn and Zn+S along with NPK significantly higher total K uptake by crop over NPK. The pooled results indicated increase of 2.58 and 7.76 per cent in total K uptake with the application of NPK+Zn and NPKS+Zn, respectively over NPK. Total K uptake recorded with the application of NPKS+Zn was also significantly more than with NPK+Zn.

4.3.3.3.4 Total S uptake

Weed management: The data reveal that total S uptake by crop was significantly increased through weed control measures over weedy check during both the years as well as on pooled basis. On pooled basis, atrazine *fb* tembotrione resulted in highest total S uptake closely followed by application of two hand weedings and alachlor *fb* tembotrione. Critical examination of data further revealed that application of alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding were statistically at par with each other but significantly superior over rest of all treatments. On pooled basis, atrazine *fb* tembotrione, two hand weedings and alachlor *fb* tembotrione enhanced total S uptake by 92.24, 89.29 and 88.91 per cent, respectively over weedy check.

Nutrient management: The pooled results indicated increase of 4.20 and 12.02 per cent in total S uptake with the application of NPK+Zn and NPKS+Zn, respectively over NPK. Similarly total S uptake recorded with the application of NPKS+Zn was also significantly more than with NPK+Zn.

4.4 SOIL ANALYSIS

4.4.1 Soil pH at 30 DAS and harvest

The data related to soil pH are presented in Table 4.19. All weed management and nutrient management treatments did not differ significantly in their effect on soil pH during both the years of experimentation as well as on pooled basis at both the stages.

4.4.2 Soil electrical conductivity (EC) at 30 DAS and at harvest

The data related to soil EC are presented in Table 4.19. All weed management and nutrient management treatments did not differ significantly in their effect on soil EC during both the years of experimentation as well as on pooled basis at both the stages.

4.4.3 Soil organic carbon at harvest

The data related to soil organic carbon are presented in Table 4.20. All weed management and nutrient management treatments did not differ significantly in their effect on soil organic carbon at harvest during both the years of experimentation as well as on pooled basis.

4.4.4 Available nutrient status

The data related to available nutrient status of soil after harvest of crop are given in Table 4.20 and 4.21.

4.4.4.1 Available Nitrogen

Weed management: Various weed management practices failed to exhibit any significant change in available nitrogen status of soil at harvest of crop during both the years and on pooled basis.

Nutrient management: No significant effect on available nitrogen status of soil at harvest of crop was observed due to varying nutrient management during both the years of experiment and on pooled basis.

4.4.4.2 Available Phosphorus

Weed management: Application of herbicides alone and in combination with hand weeding didn't significantly affect the available phosphorus status of soil at harvest of crop during both the years and on pooled basis.

Nutrient management: Irrespective of years and on pooled basis, available phosphorus status of soil at harvest of crop was not affected by the application of different nutrients.

4.4.4.3 Available Potassium

Weed management: The data explicit that there was no significant effect of weed management practices on available potassium status of soil at harvest of crop during both the years and on pooled basis.

Nutrient management: The available potassium status of soil recorded at harvest of crop was not influenced significantly by nutrient management during both the years of experimentation as well as on pooled basis.

4.4.4.4 Available Sulphur

Weed management: Different weed control measures showed no significant effect on available sulphur status of soil at harvest of crop during both the years as well as on pooled basis.

Nutrient management: A perusal of data indicated that different nutrient management treatments failed to record significant variation in available sulphur status of soil at harvest of crop during both the years and on pooled basis.

4.4.5 Soil enzyme activity

The data related to soil enzyme dehydrogenase, phosphatase and urease activity at harvest are given in Table 4.22.

Weed management: All the weed management treatments did not differ significantly in their effect on soil enzyme dehydrogenase, phosphatase and urease activity at harvest during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management also had no significant effect on soil enzyme dehydrogenase, phosphatase and urease activity at harvest during both the years of experimentation as well as pooled basis.

4.5 ECONOMIC EVALUATION

The data related to net return and B:C ratio are presented in Table 4.23.

4.5.1 Net return

Weed management: A critical examination of data explicit that all weed control treatments increased the net return over unweeded control during both the years. On pooled basis, application of atrazine *fb* tembotrione gave maximum net return of ₹ 70254 ha^{-1} followed by alachlor *fb* tembotrione, atrazine *fb* hand weeding, alachlor+atrazine *fb* hand weeding and two hand weedings which were superior over rest of the weed management treatments. The next treatment in order of superiority was alachlor *fb* hand weeding, tembotrione alone and tembotrione *fb* hand weeding also registered higher net return over weedy check.

Nutrient management: It is evident from the data that application of NPKS+Zn increased the net return from NPK and NPK+Zn but not with NPK+Zn over NPK during first year as well as on pooled basis while during second year NPKS+Zn was increased the net return over NPK with different nutrient management treatments. On pooled basis, application of NPKS+Zn recorded maximum net return (₹64862 ha^{-1}).

4.5.2 B:C ratio

Weed management: The data pertaining to B:C showed variation in different weed control treatments across the years. On pooled basis, maximum B:C ratio (2.74) was obtained through atrazine *fb* tembotrione, which was greater than rest of the treatments. The next best treatment in this aspect was alachlor *fb* tembotrione (2.70) which was higher over atrazine *fb* hand weeding (2.66), tembotrione alone (2.60), alachlor+atrazine *fb* hand weeding (2.52), alachlor *fb* hand weeding (2.52), tembotrione *fb* hand weeding (2.37) and two hand weedings (2.21).

Nutrient management: The pooled data showed that highest B:C ratio (2.48) was obtained with the application of NPK which was superior over NPKS+Zn (2.45) and NPK+Zn (2.39).

4.6 RESIDUAL STUDIES ON SUCCEDDING WHEAT

4.6.1 Weed studies

4.6.1.1 Weed density at 30 DAS

The data related to density of weeds at 30 DAS of wheat crop are given in Tables 4.24 (a) to 4.24 (d).

Weed management: All the weed management treatments did not differ significantly in their effect on density of different weeds at 30 DAS of wheat crop during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management also had no significant effect on density of different weeds at 30 DAS of wheat crop during both the years of experimentation as well as pooled basis.

4.6.1.2 Weed dry matter at 30 DAS

The data related to dry matter of weeds at 30 DAS of wheat crop are given in Table 4.25.

Weed management: All the weed management treatments did not differ significantly in their effect on weed dry matter at 30 DAS of wheat crop during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management also had no significant effect on weed dry matter at 30 DAS of wheat crop during both the years of experimentation as well as pooled basis.

4.6.2 Crop studies

4.6.2.1 Visual phytotoxicity scoring

The data related to residual effect of phytotoxicity of maize applied herbicides on wheat are presented in Table 4.26. The herbicide toxicity on crop stand and growth was recorded at 30 DAS during both the years of evaluation by visual scoring. During first year visual survey indicated slight stunting, some plant stand loss, injury and discolouration of wheat plants. However, during the second year there was no injury to wheat plants.

Table 4.26: Visual phytotoxicity of herbicides applied to maize on wheat at 30 DAS

Treatments	Visual scoring at 30 DAS	
	2015-16	**2016-17**
Weed Management		
Weedy check	0	0
Hand weeding 15 & 35 DAS	0	0
Tembotrione	2	0
Alachlor *fb* hand weeding	1	0
Atrazine *fb* hand weeding	1	0
Tembotrione *fb* hand weeding	2	0
Alachlor+atrazine *fb* hand weeding	1	0
Alachlor *fb* tembotrione	2	0
Atrazine *fb* tembotrione	2	0

4.6.2.2 Growth parameters

4.6.2.2.1 Plant height at 30 DAS and at harvest

The data related to plant height of wheat crop are presented in Table 4.27.

Weed management: All the weed management treatments did not differ significantly in their effect on plant height at 30 DAS and harvest during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management also had no significant effect on plant height at 30 DAS and at harvest during both the years of experimentation.

4.6.2.2.2 Dry matter accumulation at 30 DAS and at harvest

The data related to dry matter accumulation of wheat crop are presented in Table 4.27.

Weed management: All the weed management treatments did not differ significantly in their effect on dry matter accumulation at 30 DAS and harvest during both the years of experimentation as well as on pooled basis.

Nutrient management: Nutrient management also had no significant effect on dry matter accumulation at 30 DAS and at harvest during both the years of experimentation.

4.6.2.3 Yield parameters

The data related to yield parameters of wheat crop are presented in Table 4.28.

Weed management: Various weed management practices failed to exhibit any significant change in yield parameters *viz.*, number of tillers metre^{-1} row length, spike length, number of grain spike^{-1} and 1000-grain weight of wheat crop during both the years and on pooled basis.

Nutrient management: No significant effect on yield parameters *viz.*, number of tillers metre^{-1} row length, spike length, number of grain spike^{-1} and 1000-grain weight of wheat crop was observed due to varying nutrient management during both the years of experiment and on pooled basis.

4.6.2.4 Yield and harvest index

The data related to yield and harvest index are presented in Table 4.29.

4.6.2.4.1 Yield

Weed management: Different weed control measures showed non significant effect on grain yield, straw yield and biological yield of wheat crop during both the years as well as on pooled basis.

Nutrient management: A perusal of data indicate that different nutrient management treatments failed to cause significant variation in grain yield, straw yield and biological yield of wheat crop during both the years and on pooled basis.

4.6.2.4.2 Harvest index

Weed management: An assessment of data revealed that weed management treatments did not have any significant effect on harvest index of wheat crop in both the years and on pooled basis.

Nutrient management: In both the years and on pooled basis, harvest index of wheat crop remained unaffected by different nutrient management treatments.

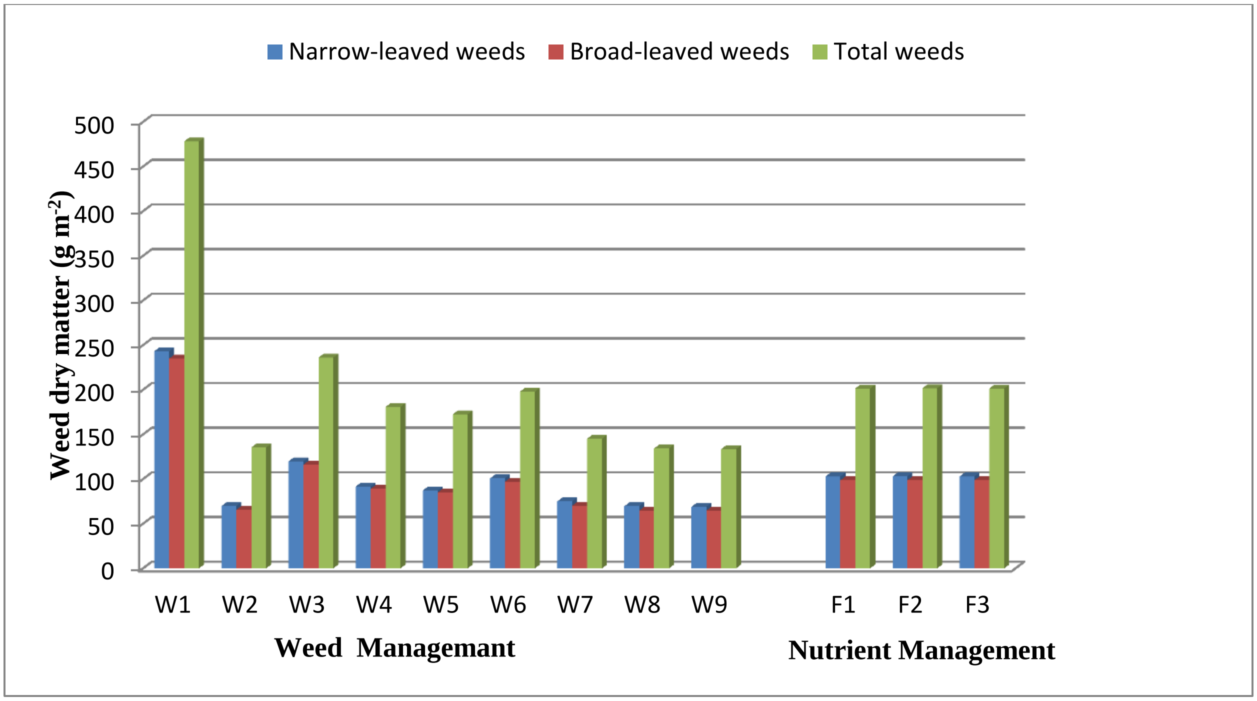


Fig. 4.1 Effect of weed management and nutrient management on weed dry matter at harvest (Pooled)

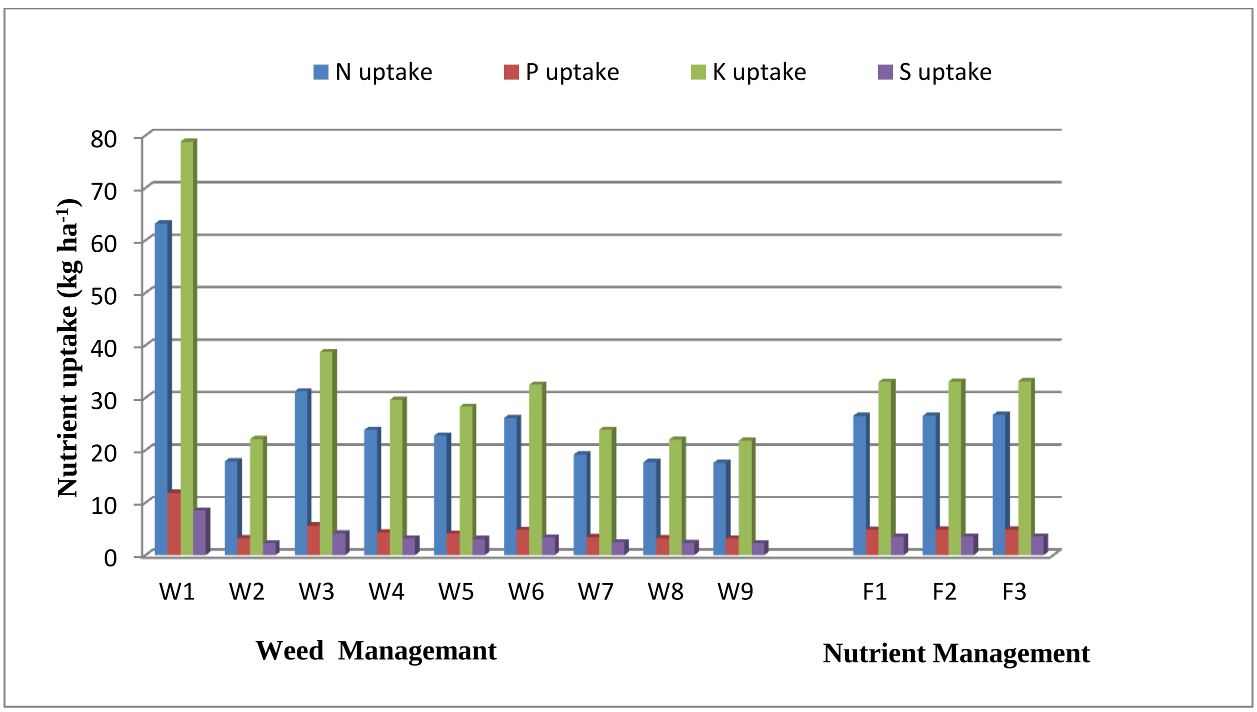


Fig. 4.2 Effect of weed management and nutrient management on N, P, K and S uptake by weeds at harvest (Pooled)

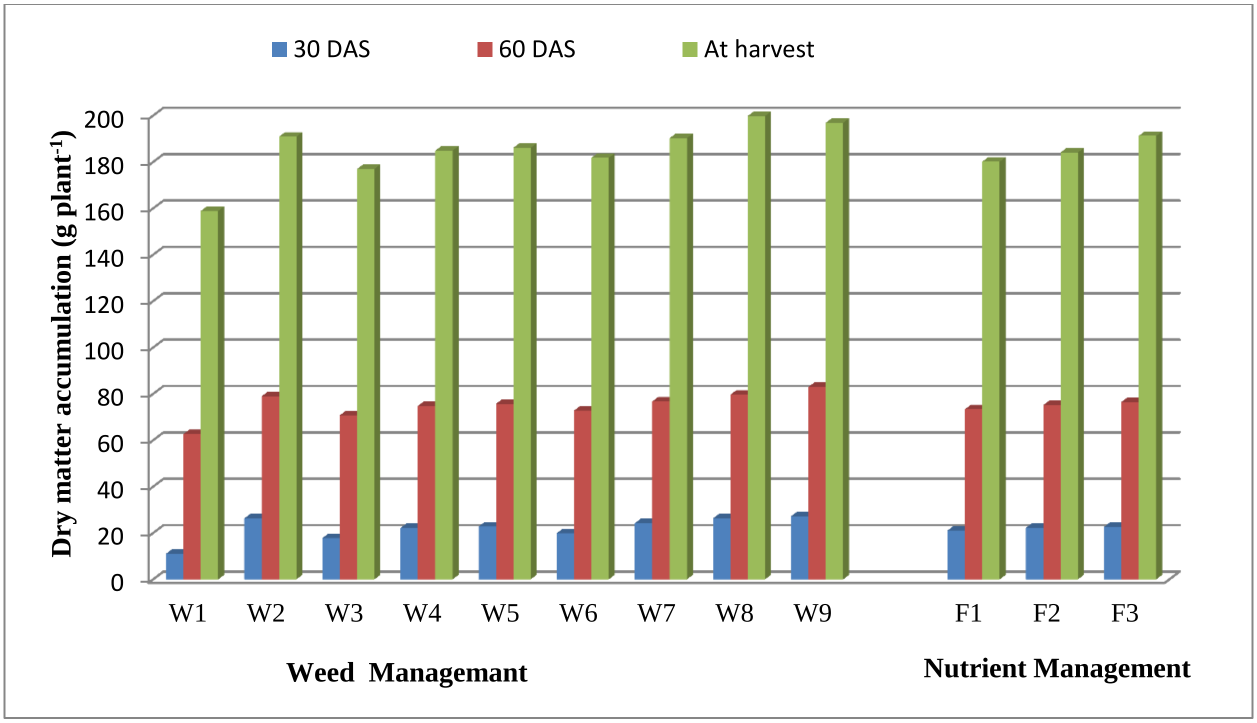


Fig. 4.3 Effect of weed management and nutrient management on crop dry matter accumulation at different crop growth stages (Pooled)

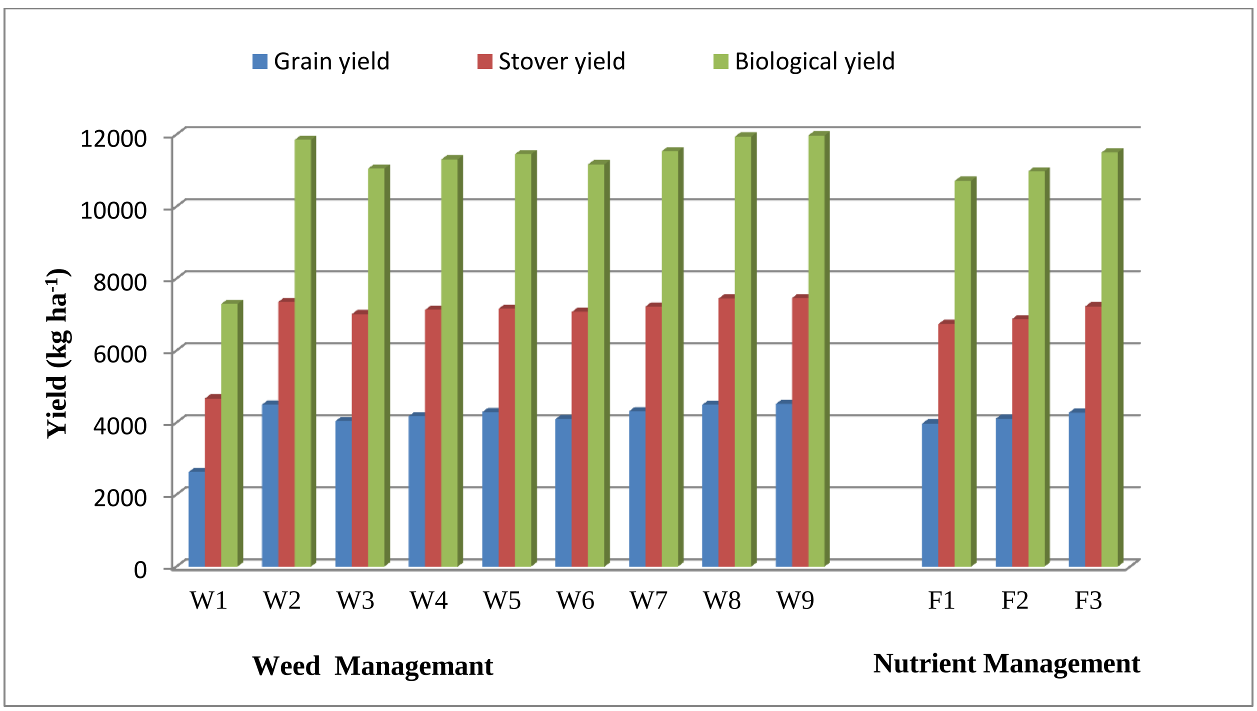


Fig. 4.4 Effect of weed management and nutrient management on grain, stover and biological yield of QPM (Pooled)

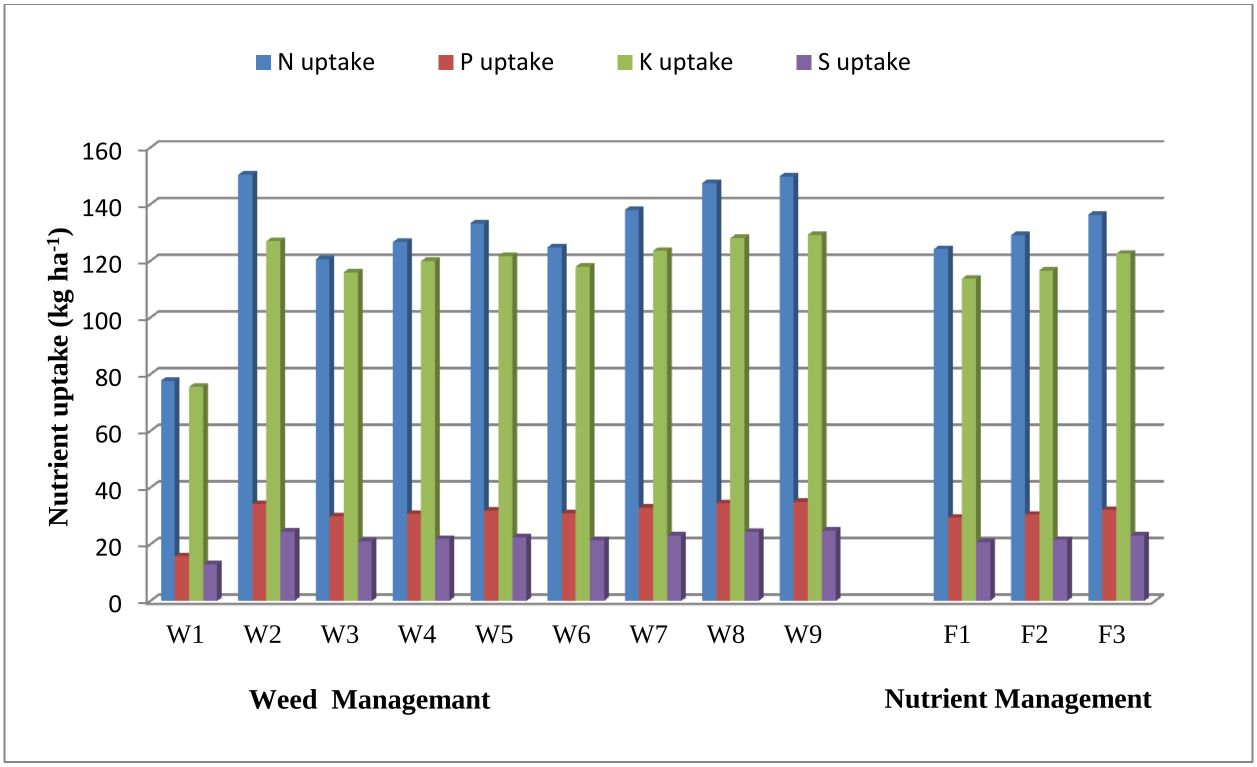


Fig. 4.5 Effect of weed management and nutrient management on total N, P, K and S uptake by QPM at harvest (Pooled)

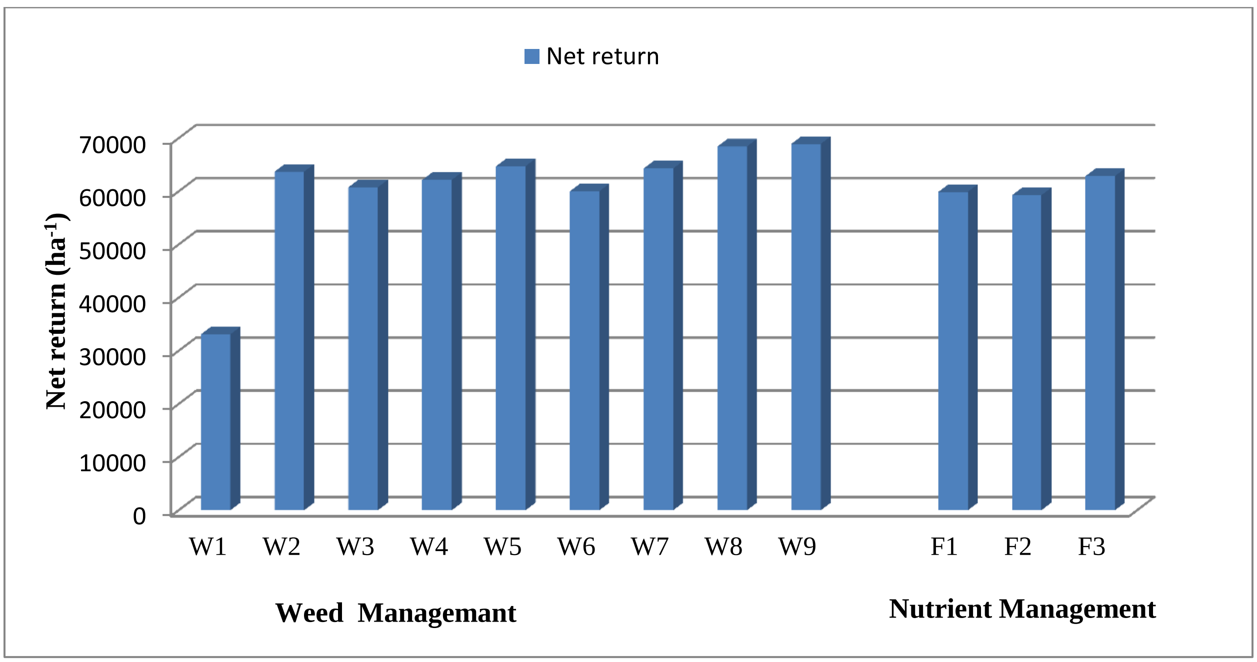


Fig. 4.6 Effect of weed management and nutrient management on net return (Pooled)

Table 4.1(a): Effect of weed management and nutrient application on weed density at 30 DAS

Treatments	Weed density (No. m^{-2})								
	Echinochloa colona			*Cynodon dactylon*			*Cyperus rotundus*		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	9.11	8.45	8.78	3.55	3.49	3.52	3.70	3.63	3.66
	(82.55)	(70.87)	(76.71)	(12.15)	(11.72)	(11.93)	(13.26)	(12.66)	(12.96)
Hand weeding 15 & 35 DAS	2.11	2.03	2.07	2.36	2.28	2.32	2.65	2.65	2.65
	(3.94)	(3.61)	(3.77)	(5.05)	(4.72)	(4.89)	(6.56)	(6.50)	(6.53)
Tembotrione	2.91	2.91	2.91	2.87	2.81	2.84	3.07	3.05	3.06
	(8.04)	(7.99)	(8.02)	(7.74)	(7.40)	(7.57)	(8.97)	(8.84)	(8.91)
Alachlor *fb* hand weeding	2.84	2.73	2.78	2.73	2.67	2.70	2.91	2.88	2.89
	(7.75)	(6.94)	(7.34)	(6.98)	(6.65)	(6.82)	(7.99)	(7.77)	(7.88)
Atrazine *fb* hand weeding	2.72	2.68	2.70	2.61	2.57	2.59	2.90	2.85	2.87
	(6.92)	(6.69)	(6.81)	(6.33)	(6.09)	(6.21)	(7.93)	(7.62)	(7.78)
Tembotrione *fb* hand weeding	2.75	2.74	2.74	2.79	2.77	2.78	3.02	2.99	3.01
	(7.12)	(7.00)	(7.06)	(7.32)	(7.19)	(7.26)	(8.66)	(8.45)	(8.55)
Alachlor+atrazine *fb* hand weeding	2.28	2.21	2.24	2.52	2.50	2.51	2.90	2.82	2.86
	(4.69)	(4.38)	(4.54)	(5.85)	(5.75)	(5.80)	(7.89)	(7.47)	(7.68)
Alachlor *fb* tembotrione	2.05	1.98	2.02	2.41	2.38	2.39	2.72	2.67	2.70
	(3.73)	(3.41)	(3.57)	(5.30)	(5.15)	(5.23)	(6.94)	(6.63)	(6.78)
Atrazine *fb* tembotrione	1.95	1.93	1.94	2.27	2.21	2.24	2.67	2.66	2.66
	(3.32)	(3.25)	(3.29)	(4.65)	(4.37)	(4.51)	(6.62)	(6.58)	(6.60)
S.Em. .±	0.12	0.05	0.06	0.04	0.03	0.02	0.06	0.04	0.03
C.D. (P = 0.05)	0.36	0.14	0.17	0.12	0.09	0.06	0.16	0.11	0.08
Nutrient management									
NPK	3.19	3.07	3.13	2.67	2.62	2.65	2.92	2.91	2.91
	(14.22)	(12.64)	(13.43)	(6.79)	(6.53)	(6.66)	(8.12)	(8.05)	(8.09)
NPK+Zn	3.18	3.07	3.12	2.68	2.63	2.65	2.97	2.90	2.94
	(14.10)	(12.68)	(13.39)	(6.79)	(6.52)	(6.66)	(8.42)	(8.02)	(8.22)
NPKS+Zn	3.21	3.08	3.14	2.69	2.64	2.67	2.96	2.92	2.94
	(14.37)	(12.74)	(13.55)	(6.87)	(6.64)	(6.76)	(8.40)	(8.10)	(8.25)
S.Em.±	0.03	0.01	0.01	0.02	0.01	0.01	0.03	0.02	0.02
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.1(b): Effect of weed management and nutrient application on weed density at 30 DAS

Treatments	Weed density (No. m^{-2})								
	Dinebra retroflexa			*Brachiaria reptans*			*Amaranthus viridis*		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management									
Weedy check	5.65	5.41	5.53	3.78	3.67	3.72	4.16	3.70	3.93
	(31.46)	(28.80)	(30.13)	(13.83)	(12.95)	(13.39)	(16.83)	(13.25)	(15.04)
Hand weeding 15 & 35 DAS	2.54	2.45	2.49	2.24	2.17	2.20	2.65	2.52	2.59
	(5.96)	(5.48)	(5.72)	(4.53)	(4.21)	(4.37)	(6.56)	(5.87)	(6.22)
Tembotrione	3.22	3.18	3.20	2.72	2.71	2.71	3.07	3.01	3.04
	(9.89)	(9.62)	(9.76)	(6.94)	(6.86)	(6.90)	(8.99)	(8.57)	(8.78)
Alachlor *fb* hand weeding	3.05	3.00	3.03	2.66	2.58	2.62	2.91	2.86	2.88
	(8.81)	(8.53)	(8.67)	(6.62)	(6.16)	(6.39)	(7.97)	(7.69)	(7.83)
Atrazine *fb* hand weeding	2.98	2.94	2.96	2.61	2.55	2.58	2.85	2.81	2.83
	(8.38)	(8.16)	(8.27)	(6.37)	(6.03)	(6.20)	(7.68)	(7.43)	(7.56)
Tembotrione *fb* hand weeding	3.12	3.09	3.10	2.69	2.64	2.66	3.01	2.98	3.00
	(9.24)	(9.03)	(9.13)	(6.76)	(6.45)	(6.61)	(8.59)	(8.37)	(8.48)
Alachlor+atrazine *fb* hand weeding	2.58	2.51	2.55	2.42	2.37	2.40	2.73	2.66	2.69
	(6.18)	(5.82)	(6.00)	(5.38)	(5.13)	(5.26)	(6.94)	(6.58)	(6.76)
Alachlor *fb* tembotrione	2.57	2.47	2.52	2.34	2.24	2.29	2.72	2.52	2.62
	(6.10)	(5.60)	(5.85)	(4.99)	(4.53)	(4.76)	(6.89)	(5.85)	(6.37)
Atrazine *fb* tembotrione	2.43	2.27	2.35	2.27	2.20	2.24	2.59	2.35	2.47
	(5.43)	(4.67)	(5.05)	(4.67)	(4.35)	(4.51)	(6.22)	(5.05)	(5.64)
S.Em. .±	0.05	0.03	0.02	0.06	0.04	0.03	0.06	0.06	0.03
C.D. (P = 0.05)	0.14	0.10	0.07	0.19	0.12	0.09	0.17	0.18	0.08
Nutrient management									
NPK	3.09	3.03	3.06	2.60	2.57	2.58	2.93	2.79	2.86
	(9.97)	(9.52)	(9.74)	(6.49)	(6.29)	(6.39)	(8.33)	(7.44)	(7.89)
NPK+Zn	3.15	3.03	3.09	2.66	2.56	2.61	2.99	2.84	2.91
	(10.27)	(9.48)	(9.88)	(6.78)	(6.26)	(6.52)	(8.63)	(7.74)	(8.18)
NPKS+Zn	3.14	3.04	3.09	2.65	2.58	2.62	2.98	2.84	2.91
	(10.25)	(9.57)	(9.91)	(6.76)	(6.35)	(6.55)	(8.60)	(7.71)	(8.16)
S.Em.±	0.03	0.02	0.02	0.04	0.02	0.02	0.04	0.04	0.02
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.1(c): Effect of weed management and nutrient application on weed density at 30 DAS

Treatments	Weed density (No. m^{-2})								
	Digera arvensis			*Trianthema portulacastrum*			*Commelina benghalensis*		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management									
Weedy check	3.55	3.42	3.49	6.19	6.08	6.14	5.27	4.66	4.96
	(12.10)	(11.23)	(11.66)	(37.88)	(36.54)	(37.21)	(27.31)	(21.20)	(24.25)
Hand weeding 15 & 35 DAS	2.33	2.23	2.28	3.42	3.34	3.38	2.39	2.29	2.34
	(4.93)	(4.47)	(4.70)	(11.24)	(10.69)	(10.96)	(5.23)	(4.77)	(5.00)
Tembotrione	2.81	2.77	2.79	3.68	3.75	3.72	2.85	2.79	2.82
	(7.39)	(7.20)	(7.29)	(13.19)	(13.66)	(13.43)	(7.66)	(7.31)	(7.49)
Alachlor *fb* hand weeding	2.72	2.69	2.71	3.66	3.61	3.63	2.70	2.66	2.68
	(6.89)	(6.77)	(6.83)	(12.92)	(12.56)	(12.74)	(6.85)	(6.63)	(6.74)
Atrazine *fb* hand weeding	2.68	2.62	2.65	3.56	3.59	3.58	2.67	2.61	2.64
	(6.71)	(6.41)	(6.56)	(12.21)	(12.42)	(12.31)	(6.68)	(6.38)	(6.53)
Tembotrione *fb* hand weeding	2.78	2.74	2.76	3.66	3.69	3.68	2.82	2.74	2.78
	(7.25)	(7.02)	(7.13)	(13.02)	(13.15)	(13.09)	(7.48)	(7.02)	(7.25)
Alachlor+atrazine *fb* hand weeding	2.44	2.40	2.42	2.76	3.45	3.10	2.52	2.47	2.49
	(5.45)	(5.28)	(5.37)	(7.20)	(11.42)	(9.31)	(5.86)	(5.61)	(5.73)
Alachlor *fb* tembotrione	2.40	2.29	2.34	3.42	3.33	3.37	2.45	2.34	2.40
	(5.24)	(4.74)	(4.99)	(11.24)	(10.59)	(10.91)	(5.51)	(5.00)	(5.25)
Atrazine *fb* tembotrione	2.32	2.19	2.25	3.39	3.19	3.29	2.40	2.33	2.37
	(4.89)	(4.29)	(4.59)	(11.06)	(9.67)	(10.36)	(5.31)	(4.95)	(5.13)
S.Em. .±	0.04	0.06	0.02	0.10	0.07	0.05	0.07	0.06	0.04
C.D. (P = 0.05)	0.13	0.19	0.06	0.30	0.20	0.14	0.22	0.18	0.10
Nutrient management									
NPK	2.65	2.60	2.63	3.73	3.77	3.75	2.87	2.77	2.82
	(6.71)	(6.39)	(6.55)	(14.32)	(14.44)	(14.38)	(8.51)	(7.67)	(8.09)
NPK+Zn	2.67	2.59	2.63	3.76	3.78	3.77	2.91	2.76	2.84
	(6.76)	(6.38)	(6.57)	(14.51)	(14.49)	(14.50)	(8.73)	(7.64)	(8.18)
NPKS+Zn	2.68	2.59	2.64	3.76	3.80	3.78	2.91	2.77	2.84
	(6.81)	(6.36)	(6.59)	(14.49)	(14.64)	(14.56)	(8.73)	(7.65)	(8.19)
S.Em.±	0.02	0.02	0.01	0.06	0.04	0.03	0.04	0.03	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.1(d): Effect of weed management and nutrient application on weed density at 30 DAS

Treatments	Weed density (No. m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	12.40 (153.24)	11.72 (137.00)	12.06 (145.12)	9.72 (94.12)	9.09 (82.22)	9.41 (88.17)	15.74 (247.36)	14.82 (219.22)	15.28 (233.29)
Hand weeding 15 & 35 DAS	5.15 (26.05)	5.00 (24.53)	5.08 (25.29)	5.33 (27.97)	5.13 (25.79)	5.23 (26.88)	7.38 (54.02)	7.13 (50.32)	7.25 (52.17)
Tembotrione	6.48 (41.58)	6.42 (40.72)	6.45 (41.15)	6.13 (37.23)	6.10 (36.73)	6.12 (36.98)	8.90 (78.82)	8.83 (77.46)	8.86 (78.14)
Alachlor *fb* hand weeding	6.21 (38.15)	6.05 (36.05)	6.13 (37.10)	5.93 (34.64)	5.84 (33.65)	5.88 (34.14)	8.56 (72.79)	8.38 (69.70)	8.47 (71.24)
Atrazine *fb* hand weeding	6.03 (35.95)	5.92 (34.59)	5.97 (35.27)	5.81 (33.29)	5.75 (32.65)	5.78 (32.97)	8.34 (69.23)	8.23 (67.24)	8.28 (68.23)
Tembotrione *fb* hand weeding	6.29 (39.10)	6.21 (38.12)	6.25 (38.61)	6.07 (36.35)	6.01 (35.57)	6.04 (35.96)	8.71 (75.44)	8.61 (73.69)	8.66 (74.57)
Alachlor+atrazine *fb* hand weeding	5.52 (30.00)	5.39 (28.55)	5.46 (29.28)	5.09 (25.45)	5.42 (28.89)	5.26 (27.17)	7.48 (55.46)	7.61 (57.45)	7.54 (56.45)
Alachlor *fb* tembotrione	5.25 (27.05)	5.08 (25.32)	5.16 (26.19)	5.42 (28.88)	5.16 (26.17)	5.29 (27.53)	7.51 (55.93)	7.21 (51.49)	7.36 (53.71)
Atrazine *fb* tembotrione	5.02 (24.70)	4.87 (23.22)	4.94 (23.96)	5.29 (27.48)	4.95 (23.97)	5.12 (25.72)	7.26 (52.18)	6.90 (47.18)	7.08 (49.68)
S.Em. .±	0.08	0.07	0.04	0.09	0.08	0.05	0.10	0.10	0.05
C.D. (P = 0.05)	0.23	0.22	0.11	0.27	0.23	0.13	0.30	0.29	0.14
Nutrient management									
NPK	6.43 (45.59)	6.29 (43.02)	6.36 (44.31)	6.04 (37.87)	5.92 (35.94)	5.98 (36.91)	8.80 (83.46)	8.61 (78.96)	8.71 (81.21)
NPK+Zn	6.50 (46.37)	6.29 (42.96)	6.40 (44.66)	6.11 (38.62)	5.95 (36.24)	6.03 (37.43)	8.91 (84.99)	8.63 (79.20)	8.77 (82.10)
NPKS+Zn	6.52 (46.65)	6.32 (43.39)	6.42 (45.02)	6.11 (38.64)	5.95 (36.36)	6.03 (37.50)	8.91 (85.29)	8.66 (79.75)	8.79 (82.52)
S.Em.±	0.05	0.03	0.03	0.05	0.03	0.02	0.06	0.03	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.2(a): Effect of weed management and nutrient application on weed density at 60 DAS

Treatments	Weed density (No. m^{-2})								
	Echinochloa colona			*Cynodon dactylon*			*Cyperus rotundus*		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management									
Weedy check	9.75	9.34	9.55	4.71	4.36	4.53	4.51	4.37	4.44
	(94.66)	(86.78)	(90.72)	(21.69)	(18.48)	(20.08)	(19.96)	(18.62)	(19.29)
Hand weeding 15 & 35 DAS	2.54	2.48	2.51	2.87	2.80	2.84	3.01	2.96	2.98
	(5.97)	(5.68)	(5.82)	(7.83)	(7.35)	(7.59)	(8.62)	(8.26)	(8.44)
Tembotrione	3.27	3.17	3.22	3.22	3.18	3.20	3.28	3.25	3.27
	(10.23)	(9.56)	(9.89)	(9.90)	(9.65)	(9.77)	(10.33)	(10.07)	(10.20)
Alachlor *fb* hand weeding	2.98	2.94	2.96	3.06	2.99	3.03	3.17	3.14	3.15
	(8.39)	(8.17)	(8.28)	(8.93)	(8.47)	(8.70)	(9.55)	(9.36)	(9.45)
Atrazine *fb* hand weeding	2.96	2.91	2.93	2.99	2.95	2.97	3.12	3.09	3.10
	(8.27)	(8.03)	(8.15)	(8.52)	(8.25)	(8.39)	(9.23)	(9.05)	(9.14)
Tembotrione *fb* hand weeding	3.13	3.07	3.10	3.16	3.16	3.16	3.24	3.22	3.23
	(9.33)	(9.01)	(9.17)	(9.51)	(9.47)	(9.49)	(10.02)	(9.89)	(9.96)
Alachlor+atrazine *fb* hand weeding	2.68	2.65	2.67	2.92	2.90	2.91	3.21	3.17	3.19
	(6.70)	(6.52)	(6.61)	(8.09)	(7.92)	(8.00)	(9.83)	(9.58)	(9.71)
Alachlor *fb* tembotrione	2.47	2.44	2.45	2.91	2.88	2.89	3.09	3.07	3.08
	(5.62)	(5.48)	(5.55)	(7.98)	(7.79)	(7.88)	(9.09)	(8.93)	(9.01)
Atrazine *fb* tembotrione	2.39	2.36	2.37	2.83	2.76	2.80	3.05	2.98	3.02
	(5.22)	(5.07)	(5.15)	(7.54)	(7.15)	(7.34)	(8.83)	(8.41)	(8.62)
S.Em. .±	0.07	0.06	0.04	0.07	0.05	0.04	0.08	0.04	0.04
C.D. (P = 0.05)	0.22	0.19	0.10	0.22	0.16	0.11	0.24	0.12	0.11
Nutrient management									
NPK	3.57	3.47	3.52	3.16	3.11	3.14	3.30	3.25	3.27
	(17.06)	(15.96)	(16.51)	(9.84)	(9.39)	(9.62)	(10.60)	(10.24)	(10.42)
NPK+Zn	3.58	3.49	3.53	3.19	3.12	3.15	3.30	3.25	3.27
	(17.18)	(16.09)	(16.63)	(10.03)	(9.44)	(9.73)	(10.59)	(10.27)	(10.43)
NPKS+Zn	3.58	3.49	3.54	3.20	3.10	3.15	3.30	3.25	3.27
	(17.22)	(16.05)	(16.64)	(10.12)	(9.35)	(9.73)	(10.62)	(10.22)	(10.42)
S.Em.±	0.01	0.05	0.01	0.05	0.03	0.02	0.05	0.02	0.02
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.2(b): Effect of weed management and nutrient application on weed density at 60 DAS

Treatments	Weed density (No. m^{-2})								
	Dinebra retroflexa			*Brachiaria reptans*			*Amaranthus viridis*		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management									
Weedy check	6.36	6.09	6.22	4.37	4.67	4.52	4.78	4.52	4.65
	(39.93)	(36.62)	(38.28)	(18.63)	(21.36)	(19.99)	(22.39)	(19.97)	(21.18)
Hand weeding 15 & 35 DAS	2.69	2.69	2.69	2.64	2.59	2.61	2.90	2.80	2.85
	(6.92)	(6.77)	(6.85)	(6.49)	(6.24)	(6.37)	(7.93)	(7.36)	(7.65)
Tembotrione	3.48	3.45	3.47	3.02	3.00	3.01	3.36	3.31	3.33
	(11.68)	(11.43)	(11.56)	(8.64)	(8.51)	(8.57)	(10.80)	(10.44)	(10.62)
Alachlor *fb* hand weeding	3.30	3.28	3.29	2.99	2.96	2.98	3.23	3.17	3.20
	(10.46)	(10.32)	(10.39)	(8.46)	(8.29)	(8.37)	(9.96)	(9.53)	(9.74)
Atrazine *fb* hand weeding	3.27	3.25	3.26	2.97	2.92	2.94	3.14	3.09	3.11
	(10.21)	(10.06)	(10.14)	(8.33)	(8.01)	(8.17)	(9.36)	(9.05)	(9.20)
Tembotrione *fb* hand weeding	3.43	3.41	3.42	3.01	2.97	2.99	3.34	3.26	3.30
	(11.29)	(11.11)	(11.20)	(8.58)	(8.33)	(8.46)	(10.69)	(10.11)	(10.40)
Alachlor+atrazine *fb* hand weeding	2.77	2.73	2.75	2.86	2.82	2.84	2.95	2.94	2.95
	(7.22)	(6.96)	(7.09)	(7.69)	(7.45)	(7.57)	(8.24)	(8.16)	(8.20)
Alachlor *fb* tembotrione	2.74	2.71	2.72	2.71	2.64	2.68	2.91	2.85	2.88
	(7.01)	(6.84)	(6.93)	(6.88)	(6.49)	(6.69)	(7.99)	(7.62)	(7.80)
Atrazine *fb* tembotrione	2.67	2.52	2.60	2.65	2.62	2.64	2.88	2.74	2.81
	(6.64)	(5.86)	(6.25)	(6.54)	(6.36)	(6.45)	(7.77)	(7.01)	(7.39)
S.Em. .±	0.01	0.05	0.05	0.05	0.05	0.03	0.06	0.05	0.03
C.D. (P = 0.05)	0.29	0.14	0.14	0.16	0.15	0.07	0.18	0.16	0.09
Nutrient management									
NPK	3.41	3.34	3.37	3.02	3.02	3.02	3.27	3.19	3.23
	(12.34)	(11.72)	(12.03)	(8.91)	(9.00)	(8.95)	(10.53)	(9.91)	(10.22)
NPK+Zn	3.40	3.35	3.37	3.03	3.02	3.03	3.27	3.18	3.23
	(12.31)	(11.78)	(12.05)	(8.94)	(9.03)	(8.98)	(10.54)	(9.91)	(10.22)
NPKS+Zn	3.43	3.35	3.39	3.02	3.02	3.02	3.29	3.19	3.24
	(12.48)	(11.82)	(12.15)	(8.90)	(8.99)	(8.94)	(10.64)	(9.93)	(10.29)
S.Em.±	0.05	0.03	0.03	0.03	0.02	0.01	0.03	0.01	0.02
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.2(c): Effect of weed management and nutrient application on weed density at 60 DAS

Treatments	Weed density (No. m^{-2})								
	Digera arvensis			*Trianthema portulacastrum*			*Commelina benghalensis*		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management									
Weedy check	4.80	4.56	4.68	6.98	6.55	6.76	5.92	5.21	5.56
	(22.64)	(20.32)	(21.48)	(48.19)	(42.38)	(45.29)	(34.56)	(26.63)	(30.60)
Hand weeding 15 & 35 DAS	2.66	2.59	2.62	3.85	3.83	3.84	2.75	2.64	2.69
	(6.66)	(6.23)	(6.45)	(14.33)	(14.23)	(14.28)	(7.34)	(6.56)	(6.95)
Tembotrione	3.21	3.19	3.20	4.10	4.09	4.09	3.21	3.19	3.20
	(9.86)	(9.68)	(9.77)	(16.31)	(16.21)	(16.26)	(9.82)	(9.68)	(9.75)
Alachlor *fb* hand weeding	3.04	3.03	3.03	4.06	4.03	4.05	3.01	2.99	3.00
	(8.81)	(8.69)	(8.75)	(15.99)	(15.78)	(15.89)	(8.62)	(8.44)	(8.53)
Atrazine *fb* hand weeding	2.97	2.95	2.96	4.02	3.99	4.00	2.97	2.95	2.96
	(8.35)	(8.20)	(8.27)	(15.66)	(15.42)	(15.54)	(8.34)	(8.18)	(8.26)
Tembotrione *fb* hand weeding	3.15	3.12	3.13	4.06	4.06	4.06	3.17	3.14	3.15
	(9.44)	(9.25)	(9.34)	(16.03)	(16.00)	(16.01)	(9.59)	(9.36)	(9.47)
Alachlor+atrazine *fb* hand weeding	2.87	2.73	2.80	3.89	3.87	3.88	2.90	2.76	2.83
	(7.84)	(6.96)	(7.40)	(14.69)	(14.46)	(14.58)	(7.98)	(7.12)	(7.55)
Alachlor *fb* tembotrione	2.79	2.68	2.74	3.85	3.83	3.84	2.88	2.73	2.81
	(7.38)	(6.72)	(7.05)	(14.30)	(14.18)	(14.24)	(7.82)	(6.99)	(7.41)
Atrazine *fb* tembotrione	2.76	2.66	2.71	3.81	3.78	3.80	2.87	2.70	2.79
	(7.12)	(6.56)	(6.84)	(14.07)	(13.82)	(13.94)	(7.75)	(6.83)	(7.29)
S.Em. .±	0.09	0.05	0.05	0.07	0.05	0.04	0.09	0.07	0.05
C.D. (P = 0.05)	0.27	0.16	0.13	0.21	0.15	0.10	0.28	0.20	0.13
Nutrient management									
NPK	3.15	3.06	3.11	4.29	4.22	4.26	3.30	3.14	3.22
	(9.84)	(9.22)	(9.53)	(18.83)	(18.06)	(18.44)	(11.35)	(9.94)	(10.65)
NPK+Zn	3.14	3.06	3.10	4.30	4.22	4.26	3.29	3.14	3.22
	(9.80)	(9.21)	(9.51)	(18.94)	(18.04)	(18.49)	(11.30)	(9.99)	(10.65)
NPKS+Zn	3.12	3.04	3.08	4.28	4.23	4.25	3.29	3.15	3.22
	(9.73)	(9.11)	(9.42)	(18.76)	(18.06)	(18.41)	(11.28)	(10.00)	(10.64)
S.Em.±	0.06	0.03	0.03	0.02	0.03	0.01	0.06	0.03	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.2(d): Effect of weed management and nutrient application on weed density at 60 DAS

Treatments	Weed density (No. m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	13.97	13.50	13.74	11.32	10.48	10.90	17.97	17.08	17.52
	(194.87)	(181.86)	(188.36)	(127.78)	(109.31)	(118.55)	(322.65)	(291.17)	(306.91)
Hand weeding 15 & 35 DAS	6.02	5.90	5.96	6.06	5.90	5.98	8.51	8.32	8.41
	(35.83)	(34.31)	(35.07)	(36.27)	(34.39)	(35.33)	(72.09)	(68.70)	(70.40)
Tembotrione	7.16	7.05	7.10	6.87	6.82	6.85	9.90	9.78	9.84
	(50.77)	(49.21)	(49.99)	(46.78)	(46.02)	(46.40)	(97.55)	(95.23)	(96.39)
Alachlor *fb* hand weeding	6.80	6.72	6.76	6.62	6.55	6.59	9.47	9.36	9.41
	(45.78)	(44.62)	(45.20)	(43.37)	(42.44)	(42.90)	(89.15)	(87.05)	(88.10)
Atrazine *fb* hand weeding	6.71	6.62	6.67	6.49	6.43	6.46	9.31	9.20	9.26
	(44.57)	(43.41)	(43.99)	(41.72)	(40.84)	(41.28)	(86.29)	(84.25)	(85.27)
Tembotrione *fb* hand weeding	7.01	6.95	6.98	6.80	6.72	6.76	9.74	9.64	9.69
	(48.74)	(47.82)	(48.28)	(45.74)	(44.72)	(45.23)	(94.48)	(92.54)	(93.51)
Alachlor+atrazine *fb* hand weeding	6.32	6.24	6.28	6.26	6.10	6.18	8.87	8.70	8.78
	(39.54)	(38.44)	(38.99)	(38.76)	(36.71)	(37.73)	(78.30)	(75.15)	(76.72)
Alachlor *fb* tembotrione	6.09	6.00	6.04	6.16	6.00	6.08	8.63	8.46	8.54
	(36.58)	(35.53)	(36.06)	(37.48)	(35.51)	(36.50)	(74.07)	(71.04)	(72.56)
Atrazine *fb* tembotrione	5.94	5.77	5.86	6.10	5.89	5.99	8.48	8.22	8.35
	(34.76)	(32.85)	(33.81)	(36.71)	(34.21)	(35.46)	(71.47)	(67.06)	(69.27)
S.Em. **.**±	0.10	0.07	0.05	0.11	0.07	0.06	0.14	0.08	0.07
C.D. (P = 0.05)	0.31	0.20	0.15	0.33	0.21	0.16	0.41	0.25	0.20
Nutrient management									
NPK	7.32	7.18	7.25	6.97	6.77	6.87	10.09	9.85	9.97
	(58.76)	(56.32)	(57.54)	(50.54)	(47.13)	(48.83)	(109.30)	(103.44)	(106.37)
NPK+Zn	7.33	7.21	7.27	6.97	6.76	6.87	10.10	9.87	9.99
	(59.04)	(56.60)	(57.82)	(50.58)	(47.15)	(48.87)	(109.63)	(103.75)	(106.69)
NPKS+Zn	7.36	7.19	7.27	6.96	6.77	6.86	10.11	9.86	9.98
	(59.34)	(56.43)	(57.89)	(50.41)	(47.10)	(48.76)	(109.75)	(103.54)	(106.64)
S.Em.±	0.05	0.04	0.02	0.04	0.03	0.02	0.05	0.04	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.3(a): Effect of weed management and nutrient application on weed dry matter at 30 DAS

Treatments	Weed dry matter (g m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	53.42	50.63	52.02	46.44	42.29	44.36	99.86	92.92	96.39
Hand weeding 15 & 35 DAS	15.97	15.55	15.76	9.32	8.88	9.10	25.30	24.43	24.86
Tembotrione	18.77	18.98	18.88	11.96	11.72	11.84	30.73	30.71	30.72
Alachlor *fb* hand weeding	17.84	17.49	17.66	10.89	10.68	10.78	28.73	28.16	28.45
Atrazine *fb* hand weeding	17.29	17.01	17.15	10.75	10.56	10.66	28.05	27.56	27.81
Tembotrione *fb* hand weeding	18.39	18.78	18.58	11.68	11.59	11.63	30.06	30.36	30.21
Alachlor+atrazine *fb* hand weeding	16.69	16.35	16.52	9.50	9.14	9.32	26.19	25.49	25.84
Alachlor *fb* tembotrione	16.08	15.86	15.97	9.16	8.79	8.98	25.25	24.64	24.95
Atrazine *fb* tembotrione	15.88	15.34	15.61	9.02	8.58	8.80	24.90	23.93	24.42
S.Em. ±	0.44	0.33	0.28	0.44	0.33	0.28	0.89	0.66	0.55
C.D. (P = 0.05)	1.33	0.99	0.80	1.33	0.99	0.80	2.66	1.99	1.60
Nutrient management									
NPK	21.13	20.69	20.91	14.29	13.60	13.94	35.42	34.29	34.85
NPK+Zn	21.23	20.67	20.95	14.39	13.58	13.98	35.62	34.25	34.93
NPKS+Zn	21.08	20.64	20.86	14.23	13.56	13.90	35.32	34.20	34.76
S.Em.±	0.25	0.17	0.15	0.25	0.17	0.15	0.49	0.34	0.30
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.3(b): Effect of weed management and nutrient application on weed dry matter at 60 DAS

Treatments	Weed dry matter (g m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	179.19	166.80	173.00	158.44	149.61	154.03	337.64	316.41	327.02
Hand weeding 15 & 35 DAS	61.54	61.39	61.46	58.82	56.65	57.73	120.36	118.03	119.20
Tembotrione	90.37	85.77	88.07	61.40	67.11	64.26	151.77	152.89	152.33
Alachlor *fb* hand weeding	74.26	71.46	72.86	67.81	60.82	64.31	142.08	132.27	137.17
Atrazine *fb* hand weeding	70.42	66.30	68.36	64.38	58.12	61.25	134.80	124.42	129.61
Tembotrione *fb* hand weeding	78.29	74.55	76.42	70.74	62.68	66.71	149.03	137.22	143.13
Alachlor+atrazine *fb* hand weeding	65.17	64.84	65.00	61.98	60.83	61.41	127.15	125.67	126.41
Alachlor *fb* tembotrione	60.89	60.52	60.70	57.76	53.93	55.84	118.65	114.45	116.55
Atrazine *fb* tembotrione	60.38	60.13	60.26	57.17	53.41	55.29	117.54	113.55	115.54
S.Em. ±	0.78	1.53	0.86	0.43	0.46	0.31	0.90	1.64	0.94
C.D. (P = 0.05)	2.34	4.60	2.48	1.28	1.38	0.90	2.70	4.92	2.70
Nutrient management									
NPK	81.77	78.65	80.21	72.75	68.81	70.78	154.52	147.46	150.99
NPK+Zn	81.82	78.73	80.27	72.81	68.86	70.84	154.64	147.59	151.11
NPKS+Zn	83.25	79.88	81.56	73.93	70.04	71.99	157.18	149.92	153.55
S.Em.±	0.42	0.36	0.28	0.19	0.17	0.13	0.47	0.38	0.30
C.D. (P=0.05)	1.21	1.03	0.78	0.55	0.48	0.36	1.34	1.09	0.85

Table 4.3(c): Effect of weed management and nutrient application on weed dry matter at harvest

Treatments	Weed dry matter (g m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	246.33	239.82	243.08	238.56	231.49	235.03	484.90	471.32	478.11
Hand weeding 15 & 35 DAS	69.37	70.08	69.72	65.97	65.28	65.62	135.34	135.36	135.35
Tembotrione	121.93	117.86	119.89	118.98	113.36	116.17	240.91	231.22	236.06
Alachlor *fb* hand weeding	94.68	88.82	91.75	91.56	86.65	89.11	186.24	175.48	180.86
Atrazine *fb* hand weeding	89.42	85.29	87.36	88.06	82.29	85.18	177.48	167.58	172.53
Tembotrione *fb* hand weeding	102.48	99.14	100.81	98.36	95.89	97.12	200.84	195.03	197.93
Alachlor+atrazine *fb* hand weeding	75.73	74.28	75.01	73.35	67.02	70.19	149.08	141.30	145.19
Alachlor *fb* tembotrione	69.82	69.43	69.62	64.80	64.88	64.75	134.62	134.31	134.38
Atrazine *fb* tembotrione	68.98	68.88	68.93	64.63	64.49	64.64	133.31	133.36	133.57
S.Em. ±	0.90	1.40	0.83	1.27	2.06	1.21	1.85	3.20	1.85
C.D. (P = 0.05)	2.69	4.21	2.40	3.81	6.17	3.48	5.56	9.58	5.32
Nutrient management									
NPK	103.92	100.95	102.44	99.81	96.18	97.99	203.73	197.13	200.43
NPK+Zn	104.00	101.28	102.64	100.17	96.49	98.33	204.17	197.77	200.97
NPKS+Zn	105.10	102.31	103.70	101.45	97.78	99.62	206.55	200.09	203.32
S.Em.±	0.36	0.37	0.26	0.40	0.41	0.28	0.53	0.60	0.40
C.D. (P=0.05)	1.03	1.06	0.73	1.14	1.16	0.80	1.53	1.71	1.13

Table 4.4: Effect of weed management and nutrient application on weed control efficiency at harvest

Treatments	Weed control efficiency (%)								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hand weeding 15 & 35 DAS	71.58	70.76	71.27	72.33	71.77	72.05	72.07	71.26	71.67
Tembotrione	50.40	50.84	50.62	50.11	51.01	50.56	50.29	50.93	50.61
Alachlor *fb* hand weeding	61.47	62.97	62.22	61.63	62.56	62.09	61.57	62.77	62.17
Atrazine *fb* hand weeding	63.60	64.42	64.01	63.07	64.40	63.74	63.37	64.42	63.89
Tembotrione *fb* hand weeding	58.29	58.65	58.47	58.76	58.52	58.64	58.54	58.59	58.57
Alachlor+atrazine *fb* hand weeding	69.21	69.00	69.11	69.23	71.00	70.12	69.24	69.99	69.61
Alachlor *fb* tembotrione	71.79	71.06	71.32	72.85	71.98	72.45	72.26	71.51	71.88
Atrazine *fb* tembotrione	71.93	71.29	71.61	72.92	72.17	72.51	72.42	71.73	72.07

Table 4.5: Effect of weed management and nutrient application on nutrient content in weeds at harvest

Treatments	Nutrient content (%)											
	N			P			K			S		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management												
Weedy check	1.315	1.328	1.322	0.247	0.249	0.248	1.646	1.648	1.647	0.175	0.179	0.177
Hand weeding 15 & 35 DAS	1.313	1.325	1.319	0.236	0.239	0.238	1.633	1.634	1.634	0.168	0.169	0.169
Tembotrione	1.314	1.328	1.321	0.245	0.231	0.238	1.639	1.643	1.641	0.174	0.176	0.175
Alachlor *fb* hand weeding	1.315	1.328	1.322	0.245	0.231	0.238	1.642	1.631	1.637	0.175	0.178	0.177
Atrazine *fb* hand weeding	1.315	1.326	1.321	0.232	0.244	0.238	1.634	1.643	1.639	0.173	0.182	0.178
Tembotrione *fb* hand weeding	1.314	1.326	1.320	0.243	0.242	0.243	1.638	1.647	1.642	0.170	0.171	0.171
Alachlor+atrazine *fb* hand weeding	1.315	1.326	1.321	0.235	0.235	0.235	1.647	1.641	1.644	0.166	0.169	0.168
Alachlor *fb* tembotrione	1.312	1.325	1.319	0.241	0.238	0.240	1.635	1.636	1.636	0.168	0.173	0.171
Atrazine *fb* tembotrione	1.312	1.326	1.319	0.238	0.238	0.238	1.633	1.631	1.632	0.168	0.172	0.170
S.Em. ±	0.016	0.018	0.012	0.004	0.004	0.003	0.022	0.022	0.016	0.003	0.004	0.002
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
NPK	1.307	1.323	1.315	0.240	0.239	0.240	1.635	1.636	1.636	0.163	0.167	0.165
NPK+Zn	1.307	1.324	1.316	0.241	0.239	0.240	1.636	1.640	1.638	0.167	0.169	0.168
NPKS+Zn	1.329	1.333	1.331	0.240	0.239	0.240	1.646	1.643	1.644	0.184	0.188	0.186
S.Em.±	0.008	0.007	0.005	0.002	0.002	0.001	0.005	0.011	0.006	0.001	0.002	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.004	0.005	0.003

Table 4.6(a): Effect of weed management and nutrient application on nutrient uptake by weeds at harvest

Treatment	Nutrient uptake (kg ha^{-1})					
	N uptake			P uptake		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management						
Weedy check	63.80	62.62	63.22	12.00	11.75	11.88
Hand weeding 15 & 35 DAS	17.78	17.97	17.88	3.20	3.25	3.23
Tembotrione	31.67	30.71	31.19	5.91	5.35	5.63
Alachlor *fb* hand weeding	24.50	23.31	23.91	4.57	4.06	4.32
Atrazine *fb* hand weeding	23.35	22.23	22.79	4.12	4.10	4.11
Tembotrione *fb* hand weeding	26.40	25.87	26.14	4.89	4.73	4.81
Alachlor+atrazine *fb* hand weeding	19.65	18.73	19.19	3.51	3.32	3.42
Alachlor *fb* tembotrione	17.67	17.81	17.74	3.25	3.20	3.22
Atrazine *fb* tembotrione	17.55	17.68	17.61	3.18	3.18	3.18
S.Em. ±	0.90	0.86	0.62	0.24	0.20	0.16
C.D. (P = 0.05)	2.71	2.57	1.79	0.73	0.61	0.46
Nutrient management						
NPK	26.83	26.28	26.55	4.96	4.77	4.86
NPK+Zn	26.84	26.31	26.58	4.96	4.77	4.87
NPKS+Zn	27.13	26.39	26.76	4.96	4.77	4.87
S.Em.±	0.24	0.24	0.17	0.06	0.05	0.04
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.6(b): Effect of weed management and nutrient application on nutrient uptake by weeds at harvest

Treatment	Nutrient uptake ($kg\ ha^{-1}$)					
	K uptake			S uptake		
	2015	2016	Pooled	2015	2016	Pooled
Weed management						
Weedy check	79.87	77.72	78.80	8.51	8.46	8.48
Hand weeding 15 & 35 DAS	22.12	22.12	22.12	2.28	2.29	2.28
Tembotrione	39.50	38.01	38.75	4.20	4.08	4.14
Alachlor *fb* hand weeding	30.59	28.63	29.61	3.27	3.13	3.20
Atrazine *fb* hand weeding	29.01	27.54	28.28	3.08	3.06	3.07
Tembotrione *fb* hand weeding	32.91	32.12	32.51	3.42	3.34	3.38
Alachlor+atrazine *fb* hand weeding	24.55	23.25	23.90	2.49	2.39	2.44
Alachlor *fb* tembotrione	21.99	22.00	22.00	2.27	2.33	2.30
Atrazine *fb* tembotrione	21.88	21.77	21.82	2.25	2.29	2.27
S.Em. ±	0.99	1.19	0.77	0.08	0.19	0.10
C.D. (P = 0.05)	2.96	3.57	2.23	0.24	0.58	0.30
Nutrient management						
NPK	33.53	32.51	33.02	3.38	3.34	3.36
NPK+Zn	33.58	32.58	33.08	3.40	3.37	3.39
NPKS+Zn	33.69	32.63	33.16	3.80	3.75	3.78
S.Em.±	0.26	0.33	0.21	0.02	0.06	0.03
CD (P=0.05)	NS	NS	NS	0.06	0.17	0.09

Table 4.7: Effect of weed management and nutrient application on plant population of QPM

Treatment	Plant population (m^{-2})					
	30 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled
Weed management						
Weedy check	6.53	6.56	6.54	6.28	6.33	6.31
Hand weeding 15 & 35 DAS	6.49	6.52	6.51	6.23	6.31	6.27
Tembotrione	6.43	6.43	6.43	6.15	6.21	6.18
Alachlor *fb* hand weeding	6.50	6.50	6.50	6.17	6.23	6.20
Atrazine *fb* hand weeding	6.48	6.48	6.48	6.12	6.15	6.14
Tembotrione *fb* hand weeding	6.49	6.45	6.47	6.22	6.19	6.20
Alachlor+atrazine *fb* hand weeding	6.44	6.40	6.42	6.07	6.19	6.13
Alachlor *fb* tembotrione	6.43	6.41	6.42	6.09	6.17	6.13
Atrazine *fb* tembotrione	6.46	6.40	6.43	6.07	6.15	6.11
S.Em. ±	0.8	0.6	0.5	1.9	1.4	1.2
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
NPK	6.46	6.44	6.45	6.16	6.20	6.18
NPK+Zn	6.49	6.44	6.47	6.18	6.23	6.20
NPKS+Zn	6.46	6.50	6.48	6.12	6.21	6.17
S.Em.±	0.4	0.3	0.2	0.4	0.6	0.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.8: Effect of weed management and nutrient application on plant height of QPM

Treatment	Plant height (cm)					
	30 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled
Weed management						
Weedy check	55.50	58.28	56.89	157.63	161.18	159.40
Hand weeding 15 & 35 DAS	72.21	76.53	74.37	204.92	208.70	206.81
Tembotrione	62.40	63.49	62.95	171.57	178.93	175.25
Alachlor *fb* hand weeding	69.90	71.18	70.54	182.45	189.73	186.09
Atrazine *fb* hand weeding	70.08	71.87	70.97	186.96	192.51	189.73
Tembotrione *fb* hand weeding	65.40	68.79	67.10	178.03	181.52	179.77
Alachlor+atrazine *fb* hand weeding	71.60	75.04	73.32	199.34	202.35	200.84
Alachlor *fb* tembotrione	73.50	78.87	76.18	207.43	210.57	209.00
Atrazine *fb* tembotrione	74.22	80.68	77.45	209.08	212.16	210.62
S.Em. ±	1.62	0.81	0.81	5.16	5.07	2.58
C.D. (P = 0.05)	4.84	2.43	2.33	15.48	15.21	7.44
Nutrient management						
NPK	66.31	70.40	68.36	185.52	190.13	187.83
NPK+Zn	69.12	71.19	70.16	188.33	192.85	190.59
NPKS+Zn	69.50	73.32	71.41	191.95	196.23	194.09
S.Em.±	0.68	0.56	0.34	1.77	1.69	0.88
CD (P=0.05)	1.95	1.61	0.96	5.06	4.85	2.49

Table 4.9: Effect of weed management and nutrient application on dry matter of QPM

Treatments	Dry matter accumulation (g plant^{-1})								
	30 DAS			60 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	9.67	9.89	9.78	54.31	56.01	55.16	139.10	140.58	139.84
Hand weeding 15 & 35 DAS	25.22	27.39	26.30	78.48	79.43	78.95	190.18	191.63	190.91
Tembotrione	17.51	18.13	17.82	70.06	71.44	70.75	175.27	178.75	177.01
Alachlor *fb* hand weeding	21.95	22.41	22.18	74.13	75.51	74.82	183.48	186.30	184.89
Atrazine *fb* hand weeding	22.72	22.89	22.81	74.99	76.38	75.69	185.28	186.94	186.11
Tembotrione *fb* hand weeding	19.46	20.34	19.90	72.33	73.31	72.82	180.01	183.63	181.82
Alachlor+atrazine *fb* hand weeding	23.35	25.12	24.23	76.00	77.44	76.72	187.73	192.79	190.26
Alachlor *fb* tembotrione	25.71	26.92	26.31	79.02	80.23	79.63	200.94	198.68	199.81
Atrazine *fb* tembotrione	26.47	28.02	27.24	82.06	83.98	83.02	193.76	200.10	196.93
S.Em. ±	0.53	0.46	0.35	2.26	1.74	1.43	6.15	3.73	3.60
C.D. (P = 0.05)	1.58	1.37	1.01	6.78	5.21	4.11	18.43	11.18	10.36
Nutrient management									
NPK	20.54	21.35	20.95	71.52	73.65	72.59	173.97	182.29	178.13
NPK+Zn	21.51	22.61	22.06	73.65	74.91	74.28	181.40	182.72	182.06
NPKS+Zn	21.96	23.07	22.52	75.29	76.02	75.65	189.89	188.13	189.01
S.Em.±	0.28	0.24	0.18	0.74	0.64	0.49	3.45	1.75	1.93
C.D. (P=0.05)	0.80	0.70	0.52	2.11	1.84	1.38	9.88	5.01	5.45

Table 4.10: Effect of weed management and nutrient application on crop growth rate (CGR) of QPM

Treatment	CGR (g m^{-2} day^{-1})					
	30 - 60 DAS			60 DAS - At Harvest		
	2015	2016	Pooled	2015	2016	Pooled
Weed management						
Weedy check	1.49	1.54	1.51	2.83	3.00	2.91
Hand weeding 15 & 35 DAS	1.78	1.73	1.76	3.72	3.74	3.73
Tembotrione	1.75	1.78	1.76	3.51	3.58	3.54
Alachlor *fb* hand weeding	1.74	1.77	1.75	3.64	3.69	3.67
Atrazine *fb* hand weeding	1.74	1.78	1.76	3.68	3.69	3.68
Tembotrione *fb* hand weeding	1.76	1.77	1.76	3.59	3.68	3.63
Alachlor+atrazine *fb* hand weeding	1.76	1.74	1.75	3.72	3.85	3.78
Alachlor *fb* tembotrione	1.78	1.78	1.78	4.06	3.95	4.01
Atrazine *fb* tembotrione	1.85	1.87	1.86	3.72	3.87	3.80
S.Em. ±	0.08	0.05	0.04	0.21	0.20	0.14
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
NPK	1.70	1.74	1.72	3.41	3.65	3.53
NPK+Zn	1.74	1.74	1.74	3.59	3.59	3.59
NPKS+Zn	1.78	1.76	1.77	3.82	3.76	3.79
S.Em.±	0.03	0.02	0.02	0.12	0.08	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.11: Effect of weed management and nutrient application on relative growth rate (RGR) of QPM

Treatment	RGR (g g^{-1} day^{-1})					
	30 - 60 DAS			60 DAS - At Harvest		
	2015	2016	Pooled	2015	2016	Pooled
Weed management						
Weedy check	0.046	0.047	0.046	0.031	0.031	0.031
Hand weeding 15 & 35 DAS	0.040	0.037	0.039	0.029	0.029	0.029
Tembotrione	0.048	0.047	0.047	0.030	0.030	0.030
Alachlor *fb* hand weeding	0.042	0.042	0.042	0.030	0.030	0.030
Atrazine *fb* hand weeding	0.041	0.042	0.041	0.030	0.030	0.030
Tembotrione *fb* hand weeding	0.046	0.044	0.045	0.030	0.031	0.030
Alachlor+atrazine *fb* hand weeding	0.041	0.039	0.040	0.030	0.030	0.030
Alachlor *fb* tembotrione	0.039	0.038	0.038	0.031	0.030	0.031
Atrazine *fb* tembotrione	0.039	0.038	0.039	0.029	0.029	0.029
S.Em. ±	0.001	0.001	0.001	0.001	0.001	0.001
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
NPK	0.0427	0.0425	0.0426	0.030	0.030	0.030
NPK+Zn	0.0421	0.0412	0.0416	0.030	0.030	0.030
NPKS+Zn	0.0422	0.0409	0.0416	0.031	0.030	0.031
S.Em.±	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.12: Visual phytotoxicity scoring of QPM at different growth stages

Treatments	Visual scoring							
	15 DAS		25 DAS		35 DAS		45 DAS	
	2015	2016	2015	2016	2015	2016	2015	2016
Weed management								
Weedy check	0	0	0	0	0	0	0	0
Hand weeding 15 & 35 DAS	0	0	0	0	0	0	0	0
Tembotrione	0	0	2	1	4	3	0	0
Alachlor *fb* hand weeding	1	1	3	1	0	0	0	0
Atrazine *fb* hand weeding	1	1	3	1	0	0	0	0
Tembotrione *fb* hand weeding	0	0	1	1	3	3	0	0
Alachlor+atrazine *fb* hand weeding	0	1	3	2	0	0	0	0
Alachlor *fb* tembotrione	0	0	3	2	4	3	0	0
Atrazine *fb* tembotrione	0	0	3	2	5	3	0	0

Table 4.13: Effect of weed management and nutrient application on days to 50% silking and yield attributes of QPM

Treatments	Days to 50% silking			Yield attributes					
				Number of grains cob^{-1}			Weight of grains (g plant^{-1})		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	45.69	47.89	46.79	262.40	266.36	264.38	49.44	57.58	53.51
Hand weeding 15 & 35 DAS	46.30	47.57	46.93	350.71	367.16	358.93	80.80	80.88	80.84
Tembotrione	47.00	48.58	47.79	300.36	308.72	304.54	70.70	71.58	71.14
Alachlor *fb* hand weeding	48.20	47.88	48.04	305.25	314.57	309.91	74.92	75.08	75.00
Atrazine *fb* hand weeding	47.89	48.11	48.00	314.06	319.49	316.78	76.30	77.19	76.74
Tembotrione *fb* hand weeding	47.57	46.57	47.07	303.80	311.22	307.51	72.90	73.33	73.11
Alachlor+atrazine *fb* hand weeding	48.58	47.29	47.94	324.77	329.56	327.17	78.90	76.39	77.65
Alachlor *fb* tembotrione	47.88	48.25	48.07	359.50	364.43	361.97	81.70	82.28	81.99
Atrazine *fb* tembotrione	48.11	48.43	48.27	365.83	369.99	367.91	82.20	83.39	82.79
S.Em. ±	1.09	0.60	0.62	4.29	4.91	3.26	0.61	0.80	0.50
C.D. (P = 0.05)	NS	NS	NS	12.86	14.73	9.39	1.82	2.39	1.44
Nutrient management									
NPK	47.36	47.67	47.52	316.89	323.99	320.44	73.35	74.54	73.94
NPK+Zn	47.68	47.93	47.80	319.55	328.64	324.10	74.08	74.82	74.45
NPKS+Zn	47.36	47.93	47.64	325.78	331.20	328.49	75.20	76.54	75.87
S.Em.±	0.35	0.28	0.22	2.13	2.02	1.47	0.27	0.31	0.21
CD (P=0.05)	NS	NS	NS	6.11	5.78	4.14	0.76	NS	0.37

Table 4.14: Effect of weed management and nutrient application on yield attributes of QPM

Treatments	Yield attributes								
	Number of cobs $plant^{-1}$			Test wt (g)			Shelling (%)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	1.01	1.04	1.03	150.01	159.20	154.61	69.64	69.20	69.42
Hand weeding 15 & 35 DAS	1.19	1.20	1.20	202.76	206.45	204.60	75.61	75.32	75.46
Tembotrione	1.12	1.14	1.13	172.30	173.30	172.80	69.40	70.07	69.73
Alachlor *fb* hand weeding	1.01	1.04	1.03	180.62	180.70	180.66	71.00	71.55	71.27
Atrazine *fb* hand weeding	1.04	1.09	1.06	182.68	184.47	183.58	71.57	72.12	71.84
Tembotrione *fb* hand weeding	1.12	1.15	1.14	176.27	177.23	176.75	71.85	72.40	72.12
Alachlor+atrazine *fb* hand weeding	1.11	1.14	1.12	194.23	199.01	196.62	73.78	74.33	74.06
Alachlor *fb* tembotrione	1.17	1.18	1.18	205.10	208.84	206.97	74.18	74.72	74.45
Atrazine *fb* tembotrione	1.22	1.24	1.23	207.31	216.75	212.03	76.84	76.33	76.58
S.Em. ±	0.06	0.08	0.05	1.19	1.05	0.80	1.37	0.63	0.75
C.D. (P = 0.05)	NS	NS	NS	3.57	3.15	2.29	4.10	1.88	2.17
Nutrient management									
NPK	1.10	1.14	1.12	184.54	188.56	186.55	71.95	72.39	72.17
NPK+Zn	1.11	1.14	1.12	185.64	188.96	187.30	72.47	72.79	72.63
NPKS+Zn	1.12	1.14	1.13	186.92	191.13	189.02	73.53	73.50	73.51
S.Em.±	0.03	0.03	0.02	0.50	0.60	0.40	0.68	0.33	0.38
CD (P=0.05)	NS	NS	NS	1.44	1.73	1.11	NS	NS	1.06

Table 4.15: Effect of weed management and nutrient application on yield and harvest index of QPM

Treatments	Yield (kg ha^{-1})									Harvest index (%)		
	Grain yield			Stover yield			Biological yield					
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management												
Weedy check	2521	2735	2628	4482	4857	4669	7002	7592	7297	35.69	36.19	35.94
Hand weeding 15 & 35 DAS	4420	4580	4500	7241	7463	7352	11660	12043	11852	37.95	37.99	37.97
Tembotrione	4001	4083	4042	6991	7030	7011	10992	11113	11053	36.45	36.69	36.57
Alachlor *fb* hand weeding	4129	4230	4179	7096	7169	7132	11224	11400	11312	36.81	37.13	36.97
Atrazine *fb* hand weeding	4268	4312	4290	7118	7206	7162	11386	11518	11452	37.51	37.38	37.44
Tembotrione *fb* hand weeding	4091	4110	4100	7008	7144	7076	11099	11254	11176	36.88	36.52	36.70
Alachlor+atrazine *fb* hand weeding	4300	4330	4315	7159	7283	7221	11459	11613	11536	37.55	37.39	37.47
Alachlor *fb* tembotrione	4454	4540	4497	7302	7595	7448	11755	12135	11945	37.87	37.46	37.66
Atrazine *fb* tembotrione	4466	4567	4516	7338	7581	7459	11804	12147	11976	37.61	37.62	37.62
S.Em. ±	142	128	95	214	152	131	296	226	186	0.96	0.77	0.61
C.D. (P = 0.05)	425	383	275	641	456	378	888	677	537	NS	NS	NS
Nutrient management												
NPK	3894	4058	3976	6614	6873	6743	10508	10931	10719	37.00	37.14	37.07
NPK+Zn	4034	4177	4105	6674	7072	6873	10708	11249	10978	37.59	37.09	37.34
NPKS+Zn	4288	4261	4275	7290	7164	7227	11578	11425	11502	36.86	37.22	37.04
S.Em.±	70	38	40	70	74	51	100	85	66	0.49	0.36	0.30
CD (P=0.05)	201	110	112	201	213	144	287	242	185	NS	NS	NS

Table 4.16: Effect of weed management and nutrient application on protein content and chlorophyll content of QPM

Treatments	Protein content in grain (%)			Chlorophyll content (mg g^{-1} f.w.)					
				30 DAS			60 DAS		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	10.30	10.63	10.46	1.617	1.618	1.617	1.734	1.746	1.740
Hand weeding 15 & 35 DAS	12.23	11.85	12.04	1.878	1.887	1.883	1.899	1.913	1.906
Tembotrione	10.78	10.88	10.83	1.710	1.724	1.717	1.822	1.805	1.814
Alachlor *fb* hand weeding	10.93	11.02	10.97	1.746	1.762	1.754	1.836	1.832	1.834
Atrazine *fb* hand weeding	10.99	11.21	11.10	1.781	1.798	1.790	1.863	1.881	1.872
Tembotrione *fb* hand weeding	10.83	10.93	10.88	1.732	1.744	1.738	1.829	1.814	1.821
Alachlor+atrazine *fb* hand weeding	11.62	11.45	11.53	1.818	1.827	1.822	1.870	1.887	1.879
Alachlor *fb* tembotrione	12.01	11.52	11.77	1.826	1.835	1.830	1.894	1.900	1.897
Atrazine *fb* tembotrione	12.12	11.68	11.90	1.841	1.848	1.844	1.909	1.918	1.913
S.Em. ±	0.20	0.18	0.14	0.022	0.022	0.016	0.021	0.015	0.013
C.D. (P = 0.05)	0.60	0.55	0.39	0.066	0.066	0.045	0.063	0.046	0.037
Nutrient management									
NPK	11.21	11.08	11.15	1.739	1.749	1.744	1.833	1.837	1.835
NPK+Zn	11.23	11.30	11.27	1.766	1.777	1.772	1.842	1.846	1.844
NPKS+Zn	11.49	11.33	11.41	1.811	1.821	1.816	1.878	1.882	1.880
S.Em.±	0.07	0.07	0.05	0.011	0.011	0.008	0.010	0.008	0.006
CD (P=0.05)	0.21	0.21	0.15	0.032	0.032	0.022	0.029	0.023	0.018

Table 4.17(a): Effect of weed management and nutrient application on nitrogen and phophorus content in grain and stover of QPM

Treatments	N content (%)						P content (%)					
	Grain			Stover			Grain			Stover		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management												
Weedy check	1.647	1.701	1.674	0.689	0.734	0.712	0.309	0.327	0.318	0.153	0.164	0.159
Hand weeding 15 & 35 DAS	1.956	1.896	1.926	0.893	0.839	0.866	0.469	0.486	0.478	0.168	0.176	0.172
Tembotrione	1.724	1.740	1.732	0.710	0.728	0.719	0.432	0.462	0.447	0.162	0.171	0.167
Alachlor *fb* hand weeding	1.749	1.762	1.756	0.730	0.762	0.746	0.441	0.457	0.449	0.163	0.172	0.168
Atrazine *fb* hand weeding	1.758	1.793	1.776	0.811	0.783	0.797	0.453	0.468	0.461	0.163	0.173	0.168
Tembotrione *fb* hand weeding	1.732	1.748	1.740	0.766	0.744	0.755	0.464	0.470	0.467	0.162	0.171	0.167
Alachlor+atrazine *fb* hand weeding	1.859	1.831	1.845	0.825	0.792	0.809	0.476	0.480	0.478	0.167	0.174	0.170
Alachlor *fb* tembotrione	1.921	1.843	1.882	0.873	0.816	0.845	0.480	0.485	0.483	0.167	0.175	0.171
Atrazine *fb* tembotrione	1.939	1.868	1.904	0.884	0.823	0.854	0.484	0.489	0.486	0.170	0.179	0.174
S.Em. ±	0.032	0.029	0.022	0.013	0.010	0.008	0.005	0.005	0.004	0.002	0.002	0.002
C.D. (P = 0.05)	0.095	0.087	0.062	0.039	0.030	0.024	0.014	0.016	0.010	0.006	0.007	0.004
Nutrient management												
NPK	1.794	1.773	1.784	0.783	0.771	0.777	0.443	0.454	0.449	0.162	0.172	0.167
NPK+Zn	1.797	1.808	1.803	0.803	0.776	0.789	0.446	0.457	0.451	0.164	0.173	0.168
NPKS+Zn	1.838	1.814	1.826	0.809	0.794	0.802	0.448	0.465	0.456	0.167	0.174	0.171
S.Em.±	0.012	0.012	0.008	0.003	0.005	0.003	0.001	0.003	0.001	0.001	0.001	0.001
CD (P=0.05)	0.034	0.034	0.023	0.009	0.015	0.008	0.002	0.008	0.004	0.003	0.002	0.002

Table 4.17(b): Effect of weed management and nutrient application on potassium and sulphur content in grain and stover of QPM

Treatments	K content (%)						S content (%)					
	Grain			Stover			Grain			Stover		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management												
Weedy check	0.423	0.435	0.429	1.354	1.385	1.369	0.291	0.298	0.295	0.106	0.111	0.108
Hand weeding 15 & 35 DAS	0.467	0.478	0.473	1.433	1.441	1.437	0.336	0.343	0.340	0.123	0.124	0.124
Tembotrione	0.437	0.440	0.439	1.389	1.412	1.401	0.319	0.321	0.320	0.116	0.117	0.117
Alachlor *fb* hand weeding	0.446	0.448	0.447	1.415	1.422	1.419	0.322	0.324	0.323	0.117	0.118	0.118
Atrazine *fb* hand weeding	0.449	0.458	0.454	1.423	1.431	1.427	0.324	0.324	0.324	0.118	0.119	0.119
Tembotrione *fb* hand weeding	0.438	0.442	0.440	1.404	1.419	1.412	0.321	0.323	0.322	0.117	0.118	0.118
Alachlor+atrazine *fb* hand weeding	0.457	0.466	0.462	1.430	1.436	1.433	0.329	0.333	0.331	0.121	0.121	0.121
Alachlor *fb* tembotrione	0.462	0.474	0.468	1.431	1.439	1.435	0.333	0.341	0.337	0.122	0.124	0.123
Atrazine *fb* tembotrione	0.478	0.488	0.483	1.435	1.442	1.439	0.338	0.344	0.341	0.125	0.125	0.125
S.Em. ±	0.005	0.005	0.004	0.019	0.022	0.014	0.004	0.004	0.003	0.002	0.002	0.001
C.D. (P = 0.05)	0.015	0.015	0.010	NS	NS	NS	0.011	0.012	0.008	0.005	0.006	0.004
Nutrient management												
NPK	0.449	0.454	0.452	1.409	1.421	1.415	0.317	0.320	0.318	0.115	0.117	0.116
NPK+Zn	0.451	0.459	0.455	1.415	1.428	1.422	0.322	0.326	0.324	0.118	0.118	0.118
NPKS+Zn	0.453	0.463	0.458	1.415	1.428	1.421	0.333	0.339	0.336	0.122	0.124	0.123
S.Em.±	0.001	0.002	0.001	0.009	0.004	0.005	0.002	0.002	0.001	0.001	0.001	0.001
CD (P=0.05)	0.002	0.007	0.003	NS	NS	NS	0.006	0.006	0.004	0.002	0.002	0.002

Table 4.18(a): Effect of weed management and nutrient application on nitrogen uptake by grain, stover and total by QPM

Treatments	N uptake (kg ha^{-1})								
	Grain			Stover			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	41.90	46.61	44.26	31.17	35.81	33.49	73.07	82.42	77.74
Hand weeding 15 & 35 DAS	86.48	86.93	86.70	64.80	62.65	63.72	151.28	149.57	150.43
Tembotrione	68.99	71.24	70.12	49.67	51.22	50.44	118.67	122.46	120.56
Alachlor *fb* hand weeding	72.25	74.56	73.40	51.83	54.67	53.25	124.09	129.23	126.66
Atrazine *fb* hand weeding	75.02	77.29	76.16	57.77	56.45	57.11	132.79	133.74	133.27
Tembotrione *fb* hand weeding	70.93	71.87	71.40	53.72	53.18	53.45	124.65	125.04	124.84
Alachlor+atrazine *fb* hand weeding	79.95	79.30	79.63	59.06	57.70	58.38	139.02	137.01	138.01
Alachlor *fb* tembotrione	85.48	83.68	84.58	63.79	62.04	62.91	149.26	145.72	147.49
Atrazine *fb* tembotrione	86.97	85.35	86.16	64.91	62.52	63.71	151.88	147.86	149.87
S.Em. ±	3.11	3.06	2.18	2.25	1.29	1.29	4.57	3.58	2.91
C.D. (P = 0.05)	9.34	9.17	6.29	6.76	3.87	3.74	13.72	10.75	8.37
Nutrient management									
NPK	70.27	72.53	71.40	52.57	53.04	52.81	122.84	125.57	124.21
NPK+Zn	73.17	75.65	74.41	53.88	55.48	54.68	127.05	131.13	129.09
NPKS+Zn	79.22	77.43	78.33	59.13	56.88	58.00	138.35	134.32	136.33
S.Em.±	1.32	0.85	0.78	0.61	0.80	0.50	1.50	1.09	0.93
CD (P=0.05)	3.77	2.44	2.21	1.74	2.28	1.41	4.30	3.12	2.61

Table 4.18(b): Effect of weed management and nutrient application on phophorus uptake by grain, stover and total by QPM

Treatments	P uptake (kg ha^{-1})								
	Grain			Stover			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	7.83	8.96	8.39	6.89	8.01	7.45	14.71	16.97	15.84
Hand weeding 15 & 35 DAS	20.74	22.25	21.49	12.19	13.17	12.68	32.93	35.41	34.17
Tembotrione	17.30	18.91	18.10	11.35	12.05	11.70	28.65	30.95	29.80
Alachlor *fb* hand weeding	18.22	19.34	18.78	11.60	12.36	11.98	29.82	31.70	30.76
Atrazine *fb* hand weeding	19.35	20.18	19.76	11.63	12.49	12.06	30.98	32.67	31.82
Tembotrione *fb* hand weeding	19.00	19.33	19.17	11.39	12.24	11.81	30.39	31.58	30.98
Alachlor+atrazine *fb* hand weeding	20.48	20.77	20.63	11.95	12.70	12.32	32.43	33.47	32.95
Alachlor *fb* tembotrione	21.39	22.02	21.71	12.23	13.32	12.77	33.62	35.34	34.48
Atrazine *fb* tembotrione	21.65	22.36	22.01	12.49	13.55	13.02	34.14	35.91	35.03
S.Em. ±	0.62	0.65	0.45	0.45	0.35	0.29	0.91	0.83	0.61
C.D. (P = 0.05)	1.87	1.94	1.29	1.35	1.04	0.82	2.71	2.49	1.77
Nutrient management									
NPK	17.53	18.71	18.12	10.73	11.84	11.28	28.26	30.55	29.40
NPK+Zn	18.27	19.34	18.81	10.99	12.26	11.63	29.26	31.61	30.43
NPKS+Zn	19.52	19.99	19.75	12.19	12.52	12.36	31.71	32.51	32.11
S.Em.±	0.32	0.16	0.18	0.15	0.14	0.10	0.36	0.23	0.22
CD (P=0.05)	0.92	0.45	0.51	0.44	0.40	0.30	1.05	0.65	0.61

Table 4.18(c): Effect of weed management and nutrient application on potassium uptake by grain, stover and total by QPM

Treatments	K uptake (kg ha^{-1})								
	Grain			Stover			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	10.70	11.91	11.31	60.89	67.56	64.23	71.59	79.47	75.53
Hand weeding 15 & 35 DAS	20.65	21.88	21.27	103.80	107.59	105.69	124.46	129.47	126.96
Tembotrione	17.50	18.01	17.75	97.18	99.30	98.24	114.67	117.30	115.99
Alachlor *fb* hand weeding	18.43	18.97	18.70	100.46	101.98	101.22	118.89	120.94	119.92
Atrazine *fb* hand weeding	19.18	19.75	19.46	101.33	103.14	102.24	120.51	122.90	121.70
Tembotrione *fb* hand weeding	17.93	18.18	18.06	98.46	101.40	99.93	116.39	119.58	117.99
Alachlor+atrazine *fb* hand weeding	19.67	20.19	19.93	102.60	104.65	103.62	122.27	124.83	123.55
Alachlor *fb* tembotrione	20.59	21.52	21.06	104.62	109.32	106.97	125.21	130.85	128.03
Atrazine *fb* tembotrione	21.44	22.30	21.87	105.29	109.33	107.31	126.73	131.63	129.18
S.Em. ±	0.71	0.64	0.48	4.00	2.97	2.50	4.38	3.22	2.72
C.D. (P = 0.05)	2.14	1.91	1.38	12.00	8.90	7.17	13.12	9.67	7.83
Nutrient management									
NPK	17.54	18.52	18.03	93.50	97.91	95.71	111.04	116.43	113.73
NPK+Zn	18.27	19.26	18.77	94.67	101.12	97.89	112.94	120.38	116.66
NPKS+Zn	19.55	19.79	19.67	103.38	102.39	102.88	122.93	122.18	122.55
S.Em.±	0.33	0.15	0.18	1.24	1.12	0.83	1.31	1.14	0.87
CD (P=0.05)	0.93	0.44	0.51	3.56	3.20	2.35	3.76	3.27	2.45

Table 4.18(d): Effect of weed management and nutrient application on sulphur uptake by grain, stover and total by QPM

Treatments	S uptake (kg ha^{-1})								
	Grain			Stover			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	7.39	8.20	7.80	4.79	5.41	5.10	12.18	13.61	12.89
Hand weeding 15 & 35 DAS	14.87	15.71	15.29	8.93	9.28	9.11	23.80	24.99	24.40
Tembotrione	12.78	13.14	12.96	8.14	8.25	8.20	20.92	21.40	21.16
Alachlor *fb* hand weeding	13.31	13.72	13.52	8.33	8.49	8.41	21.65	22.21	21.93
Atrazine *fb* hand weeding	13.84	13.97	13.91	8.43	8.60	8.52	22.27	22.58	22.42
Tembotrione *fb* hand weeding	13.15	13.29	13.22	8.23	8.46	8.34	21.38	21.75	21.56
Alachlor+atrazine *fb* hand weeding	14.14	14.41	14.28	8.71	8.84	8.78	22.85	23.25	23.05
Alachlor *fb* tembotrione	14.83	15.49	15.16	8.94	9.43	9.19	23.78	24.92	24.35
Atrazine *fb* tembotrione	15.13	15.73	15.43	9.23	9.47	9.35	24.36	25.20	24.78
S.Em. ±	0.51	0.44	0.34	0.33	0.21	0.20	0.74	0.57	0.46
C.D. (P = 0.05)	1.52	1.33	0.97	0.98	0.63	0.56	2.22	1.70	1.34
Nutrient management									
NPK	12.50	13.16	12.83	7.67	8.09	7.88	20.17	21.26	20.72
NPK+Zn	13.09	13.71	13.40	7.95	8.44	8.19	21.04	22.15	21.59
NPKS+Zn	14.22	14.35	14.28	8.96	8.88	8.92	23.18	23.23	23.21
S.Em.±	0.25	0.12	0.14	0.11	0.11	0.08	0.30	0.18	0.18
CD (P=0.05)	0.73	0.35	0.40	0.33	0.32	0.22	0.87	0.54	0.51

Table 4.19: Effect of weed management and nutrient application on soil pH and EC

Treatments	Soil pH						Soil EC (dsm^{-1})					
	30 DAS			At harvest			30 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management												
Weedy check	8.21	8.23	8.22	8.19	8.20	8.19	0.847	0.842	0.845	0.835	0.853	0.844
Hand weeding 15 & 35 DAS	8.29	8.28	8.29	8.26	8.28	8.27	0.865	0.865	0.865	0.876	0.885	0.880
Tembotrione	8.21	8.22	8.22	8.20	8.23	8.22	0.835	0.856	0.845	0.855	0.855	0.855
Alachlor *fb* hand weeding	8.22	8.22	8.22	8.20	8.23	8.22	0.855	0.825	0.840	0.835	0.855	0.845
Atrazine *fb* hand weeding	8.22	8.23	8.22	8.21	8.24	8.22	0.825	0.825	0.825	0.855	0.855	0.855
Tembotrione *fb* hand weeding	8.23	8.23	8.23	8.22	8.23	8.22	0.825	0.825	0.825	0.855	0.855	0.855
Alachlor+atrazine *fb* hand weeding	8.27	8.25	8.26	8.25	8.26	8.25	0.835	0.836	0.835	0.855	0.866	0.860
Alachlor *fb* tembotrione	8.28	8.28	8.28	8.25	8.27	8.26	0.835	0.855	0.845	0.865	0.875	0.870
Atrazine *fb* tembotrione	8.28	8.29	8.29	8.26	8.28	8.27	0.855	0.866	0.861	0.885	0.875	0.880
S.Em. ±	0.09	0.10	0.07	0.10	0.04	0.05	0.018	0.011	0.011	0.018	0.011	0.011
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
NPK	8.25	8.25	8.25	8.23	8.25	8.24	0.841	0.840	0.840	0.857	0.860	0.859
NPK+Zn	8.24	8.25	8.25	8.23	8.25	8.24	0.842	0.843	0.842	0.857	0.865	0.861
NPKS+Zn	8.24	8.25	8.25	8.23	8.25	8.24	0.843	0.849	0.846	0.858	0.867	0.862
S.Em.±	0.05	0.05	0.03	0.05	0.01	0.02	0.009	0.005	0.005	0.007	0.005	0.004
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.20: Effect of weed management and nutrient application on soil organic carbon, available nitrogen and phosphorus in soil at harvest of QPM

Treatments	Organic carbon (g kg^{-1})			Available nutrient (kg ha^{-1})					
				Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	7.81	7.78	7.79	311.14	297.29	304.21	22.01	21.51	21.76
Hand weeding 15 & 35 DAS	7.58	7.59	7.58	335.23	332.45	333.84	24.69	23.60	24.14
Tembotrione	6.89	6.96	6.92	327.82	326.29	327.05	21.18	21.07	21.13
Alachlor *fb* hand weeding	6.88	6.95	6.92	328.69	327.48	328.08	21.22	21.15	21.19
Atrazine *fb* hand weeding	6.90	7.00	6.95	329.56	328.65	329.10	21.42	21.31	21.37
Tembotrione *fb* hand weeding	6.96	6.89	6.93	328.24	325.03	326.63	21.95	21.71	21.83
Alachlor+atrazine *fb* hand weeding	7.37	7.35	7.36	331.11	330.56	330.83	22.47	21.71	22.09
Alachlor *fb* tembotrione	7.44	7.68	7.56	327.65	330.44	329.05	23.58	22.16	22.87
Atrazine *fb* tembotrione	7.60	7.59	7.59	336.02	335.23	335.62	25.25	24.69	24.97
S.Em. ±	0.26	0.27	0.19	9.32	10.93	7.18	1.19	1.09	0.81
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	7.32	7.23	7.27	327.16	325.65	326.41	22.59	22.10	22.35
NPK+Zn	7.23	7.39	7.31	328.15	325.93	327.04	22.65	22.12	22.39
NPKS+Zn	7.27	7.31	7.29	329.84	326.22	328.03	22.68	22.08	22.38
S.Em.±	0.08	0.11	0.07	3.21	3.01	2.20	0.26	0.22	0.17
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.21: Effect of weed management and nutrient application on available potassium and sulphur in soil at harvest of QPM

Treatments	Available Potassium (kg ha^{-1})			Available Sulphur (mg kg^{-1})		
	2015	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Weed management						
Weedy check	480.38	492.99	486.68	19.96	19.97	19.97
Hand weeding 15 & 35 DAS	542.36	540.48	541.42	22.18	22.13	22.16
Tembotrione	533.82	533.28	533.55	20.16	19.51	19.84
Alachlor *fb* hand weeding	535.70	534.14	534.92	20.70	20.62	20.66
Atrazine *fb* hand weeding	536.19	535.58	535.88	21.47	21.36	21.42
Tembotrione *fb* hand weeding	535.43	533.99	534.71	20.33	19.88	20.11
Alachlor+atrazine *fb* hand weeding	538.93	536.11	537.52	22.81	22.22	22.51
Alachlor *fb* tembotrione	541.67	539.38	540.52	22.08	22.03	22.05
Atrazine *fb* tembotrione	556.99	542.30	549.64	22.32	22.16	22.24
S.Em. ±	17.99	17.99	12.72	0.74	0.84	0.56
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
NPK	533.30	530.85	532.07	21.20	20.93	21.07
NPK+Zn	533.21	532.00	532.61	21.36	21.07	21.21
NPKS+Zn	533.98	533.23	533.61	21.44	21.29	21.37
S.Em.±	4.95	5.87	3.84	0.25	0.25	0.17
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.22: Effect of weed management and nutrient application on soil enzyme activity at harvest of QPM

Treatments	Soil enzyme activity (μg g^{-1} h^{-1})								
	Dehydrogenase			Phosphatase			Urease		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management									
Weedy check	118.85	126.70	122.78	205.72	209.42	207.57	324.75	348.85	336.80
Hand weeding 15 & 35 DAS	140.06	136.39	138.23	230.68	225.25	227.96	369.77	360.52	365.14
Tembotrione	120.54	128.80	124.67	209.23	215.36	212.30	320.49	342.34	331.41
Alachlor *fb* hand weeding	128.10	126.97	127.53	211.75	210.33	211.04	338.24	336.11	337.18
Atrazine *fb* hand weeding	121.47	136.71	129.09	182.77	184.44	183.61	318.53	365.06	341.80
Tembotrione *fb* hand weeding	131.90	129.75	130.82	219.08	225.53	222.30	349.85	343.60	346.72
Alachlor+atrazine *fb* hand weeding	126.54	137.26	131.90	189.99	220.12	205.06	336.50	367.36	351.93
Alachlor *fb* tembotrione	136.80	137.03	136.91	210.90	232.48	221.69	356.53	356.60	356.57
Atrazine *fb* tembotrione	136.66	143.71	140.18	219.49	234.45	226.97	354.75	376.98	365.86
S.Em. ±	5.11	6.73	4.23	9.40	11.57	7.46	11.68	17.88	10.68
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	127.64	132.08	129.86	207.87	216.61	212.24	340.05	350.67	345.36
NPK+Zn	128.55	133.12	130.84	209.70	215.18	212.44	341.46	355.39	348.42
NPKS+Zn	130.79	135.89	133.34	208.96	220.67	214.82	341.63	359.75	350.69
S.Em.±	1.35	2.87	1.58	2.51	2.61	1.81	3.77	6.37	3.70
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.23: Effect of weed management and nutrient application on net return and B:C ratio of QPM

Treatment	Net return (₹ ha^{-1})			B:C ratio		
	2015	2016	Pooled	2015	2016	Pooled
Weed management						
Weedy check	31304	37530	34417	1.56	1.69	1.63
Hand weeding 15 & 35 DAS	61855	68224	65039	2.12	2.29	2.21
Tembotrione	59965	64236	62101	2.54	2.65	2.60
Alachlor *fb* hand weeding	61084	65869	63476	2.46	2.59	2.52
Atrazine *fb* hand weeding	64080	68028	66054	2.42	2.91	2.66
Tembotrione *fb* hand weeding	59557	63132	61344	2.32	2.42	2.37
Alachlor+atrazine *fb* hand weeding	63705	67559	65632	2.42	2.62	2.52
Alachlor *fb* tembotrione	67079	72467	69773	2.65	2.75	2.70
Atrazine *fb* tembotrione	67507	73001	70254	2.61	2.87	2.74
S.Em. ±	2547	2046	1794			
C.D. (P = 0.05)	7636	6035	5379	-	-	-
Nutrient management						
NPK	56826	62982	59904	2.41	2.56	2.48
NPK+Zn	58115	64414	61265	2.27	2.50	2.39
NPKS+Zn	63771	65952	64862	2.36	2.55	2.45
S.Em. ±	1141	553	615	-	-	-
C.D. (P = 0.05)	3273	1578	1765	-	-	-

Table 4.24(a): Residual effect of weed management and nutrient application on weed density at 30 DAS in succeeding wheat

Treatments	Weed density (No. m^{-2})								
	Phalaris minor			*Avena fatua*			*Amaranthus viridis*		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management									
Weedy check	3.33	3.26	3.30	1.91	1.89	1.90	4.99	5.35	5.17
	(10.61)	(10.17)	(10.39)	(3.15)	(3.08)	(3.11)	(24.44)	(28.17)	(26.30)
Hand weeding 15 & 35 DAS	3.13	3.16	3.14	1.83	1.81	1.82	4.96	5.07	5.01
	(9.29)	(9.49)	(9.39)	(2.87)	(2.79)	(2.83)	(24.15)	(25.17)	(24.66)
Tembotrione	3.22	3.28	3.25	1.86	1.81	1.83	4.93	5.21	5.07
	(9.91)	(10.25)	(10.08)	(2.95)	(2.79)	(2.87)	(23.76)	(26.69)	(25.23)
Alachlor *fb* hand weeding	3.28	3.13	3.20	1.91	1.87	1.89	4.92	5.17	5.05
	(10.27)	(9.29)	(9.78)	(3.13)	(3.00)	(3.07)	(23.81)	(26.31)	(25.06)
Atrazine *fb* hand weeding	3.24	3.13	3.19	1.86	1.85	1.85	5.05	5.05	5.05
	(10.03)	(9.30)	(9.67)	(2.96)	(2.91)	(2.94)	(24.99)	(25.06)	(25.02)
Tembotrione *fb* hand weeding	3.21	3.22	3.22	1.85	1.86	1.85	4.96	5.20	5.08
	(9.87)	(9.90)	(9.89)	(2.93)	(2.95)	(2.94)	(24.22)	(26.58)	(25.40)
Alachlor+atrazine *fb* hand weeding	3.20	3.19	3.20	1.87	1.83	1.85	4.85	5.09	4.97
	(9.77)	(9.72)	(9.74)	(3.01)	(2.84)	(2.92)	(23.09)	(25.44)	(24.27)
Alachlor *fb* tembotrione	3.24	3.14	3.19	1.88	1.83	1.85	4.99	5.10	5.05
	(10.01)	(9.36)	(9.69)	(3.03)	(2.85)	(2.94)	(24.44)	(25.60)	(25.02)
Atrazine *fb* tembotrione	3.17	3.16	3.16	1.83	1.86	1.84	4.90	5.09	4.99
	(9.57)	(9.49)	(9.53)	(2.84)	(2.98)	(2.91)	(23.58)	(25.41)	(24.49)
S.Em. .±	0.05	0.05	0.02	0.02	0.02	0.01	0.10	0.08	0.05
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	3.21	3.18	3.19	1.87	1.84	1.86	4.92	5.15	5.04
	(9.80)	(9.62)	(9.71)	(2.99)	(2.90)	(2.94)	(23.84)	(26.05)	(24.95)
NPK+Zn	3.22	3.19	3.20	1.87	1.84	1.86	5.02	5.15	5.08
	(9.91)	(9.67)	(9.79)	(2.99)	(2.90)	(2.95)	(24.68)	(26.02)	(25.35)
NPKS+Zn	3.25	3.19	3.22	1.86	1.85	1.86	4.91	5.15	5.03
	(10.07)	(9.70)	(9.88)	(2.98)	(2.92)	(2.95)	(23.64)	(26.07)	(24.86)
S.Em.±	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.02	0.02
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.24(b): Residual effect of weed management and nutrient application on weed density at 30 DAS in succeeding wheat

Treatments	Weed density (No. m^{-2})								
	Anagallis arvensis			*Chenopodium album*			*Chenopodium murale*		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management									
Weedy check	1.95	1.88	1.91	4.66	4.69	4.67	3.82	4.01	3.91
	(3.30)	(3.04)	(3.17)	(21.29)	(21.47)	(21.38)	(14.19)	(15.94)	(15.06)
Hand weeding 15 & 35 DAS	1.92	1.81	1.87	4.57	4.33	4.45	3.60	3.82	3.71
	(3.21)	(2.79)	(3.00)	(20.37)	(18.33)	(19.35)	(12.56)	(14.11)	(13.33)
Tembotrione	1.86	1.84	1.85	4.64	4.57	4.61	3.69	3.93	3.81
	(2.95)	(2.87)	(2.91)	(21.09)	(20.39)	(20.74)	(13.22)	(14.97)	(14.09)
Alachlor *fb* hand weeding	1.87	1.88	1.87	4.55	4.57	4.56	3.71	3.83	3.77
	(3.01)	(3.03)	(3.02)	(20.24)	(20.40)	(20.32)	(13.31)	(14.17)	(13.74)
Atrazine *fb* hand weeding	1.88	1.79	1.83	4.56	4.47	4.52	3.56	3.84	3.70
	(3.05)	(2.70)	(2.88)	(20.35)	(19.52)	(19.93)	(12.23)	(14.25)	(13.24)
Tembotrione *fb* hand weeding	1.88	1.87	1.88	4.54	4.37	4.46	3.64	3.81	3.73
	(3.05)	(3.00)	(3.03)	(20.13)	(18.62)	(19.37)	(12.82)	(14.05)	(13.44)
Alachlor+atrazine *fb* hand weeding	1.75	1.86	1.81	4.56	4.33	4.45	4.16	3.82	3.99
	(2.60)	(2.96)	(2.78)	(20.35)	(18.33)	(19.34)	(17.23)	(14.11)	(15.67)
Alachlor *fb* tembotrione	1.75	1.86	1.80	4.53	4.35	4.44	3.44	3.93	3.69
	(2.57)	(2.95)	(2.76)	(20.06)	(18.46)	(19.26)	(11.38)	(14.97)	(13.17)
Atrazine *fb* tembotrione	1.89	1.85	1.87	4.66	4.34	4.50	3.55	3.87	3.71
	(3.08)	(2.93)	(3.00)	(21.29)	(18.41)	(19.85)	(12.16)	(14.50)	(13.33)
S.Em. .±	0.04	0.04	0.03	0.07	0.10	0.06	0.14	0.12	0.09
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	1.85	1.84	1.85	4.58	4.42	4.50	3.64	3.87	3.76
	(2.95)	(2.90)	(2.92)	(20.53)	(19.07)	(19.80)	(12.93)	(14.53)	(13.73)
NPK+Zn	1.87	1.85	1.86	4.59	4.44	4.51	3.65	3.88	3.77
	(3.00)	(2.95)	(2.98)	(20.57)	(19.31)	(19.94)	(12.99)	(14.59)	(13.79)
NPKS+Zn	1.86	1.85	1.86	4.59	4.48	4.54	3.76	3.88	3.82
	(2.99)	(2.91)	(2.95)	(20.62)	(19.60)	(20.11)	(13.77)	(14.57)	(14.17)
S.Em.±	0.01	0.01	0.01	0.02	0.02	0.01	0.06	0.03	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.24(c): Residual effect of weed management and nutrient application on weed density at 30 DAS in succeeding wheat

Treatments	Weed density (No. m^{-2})								
	Convolvlous arvensis			*Melilotus indica*			*Malva parviflora*		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management									
Weedy check	5.63	5.42	5.52	3.03	2.95	2.99	2.98	2.72	2.85
	(31.20)	(28.94)	(30.07)	(8.71)	(8.20)	(8.46)	(8.43)	(6.89)	(7.66)
Hand weeding 15 & 35 DAS	5.28	5.39	5.34	2.96	2.80	2.88	2.90	2.69	2.80
	(27.38)	(28.62)	(28.00)	(8.25)	(7.32)	(7.79)	(7.90)	(6.76)	(7.33)
Tembotrione	5.58	5.34	5.46	3.00	2.85	2.93	2.99	2.56	2.78
	(30.65)	(28.09)	(29.37)	(8.52)	(7.66)	(8.09)	(8.47)	(6.04)	(7.26)
Alachlor *fb* hand weeding	5.28	5.26	5.27	2.94	2.81	2.87	2.84	2.61	2.73
	(27.38)	(27.28)	(27.33)	(8.12)	(7.43)	(7.78)	(7.60)	(6.34)	(6.97)
Atrazine *fb* hand weeding	5.43	4.87	5.15	2.93	2.84	2.89	2.88	2.58	2.73
	(29.04)	(23.50)	(26.27)	(8.11)	(7.56)	(7.84)	(7.81)	(6.16)	(6.98)
Tembotrione *fb* hand weeding	5.39	5.00	5.20	2.95	2.88	2.92	2.87	2.57	2.72
	(28.62)	(24.57)	(26.59)	(8.20)	(7.83)	(8.01)	(7.72)	(6.09)	(6.91)
Alachlor+atrazine *fb* hand weeding	5.29	5.37	5.33	2.93	2.91	2.92	2.84	2.55	2.70
	(27.49)	(28.39)	(27.94)	(8.11)	(7.95)	(8.03)	(7.61)	(6.02)	(6.81)
Alachlor *fb* tembotrione	5.30	5.31	5.31	2.95	2.80	2.87	2.88	2.62	2.75
	(27.64)	(27.76)	(27.70)	(8.20)	(7.32)	(7.76)	(7.78)	(6.38)	(7.08)
Atrazine *fb* tembotrione	5.27	5.06	5.16	2.93	2.91	2.92	2.82	2.57	2.70
	(27.26)	(25.36)	(26.31)	(8.11)	(8.00)	(8.05)	(7.47)	(6.11)	(6.79)
S.Em. .±	0.08	0.13	0.07	0.03	0.03	0.02	0.04	0.04	0.03
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	5.37	5.17	5.27	2.95	2.85	2.90	2.88	2.61	2.75
	(28.42)	(26.37)	(27.40)	(8.20)	(7.67)	(7.94)	(7.82)	(6.32)	(7.07)
NPK+Zn	5.38	5.28	5.33	2.96	2.88	2.92	2.88	2.61	2.74
	(28.54)	(27.55)	(28.04)	(8.26)	(7.81)	(8.04)	(7.79)	(6.30)	(7.05)
NPKS+Zn	5.39	5.23	5.31	2.97	2.85	2.91	2.91	2.61	2.76
	(28.60)	(26.91)	(27.75)	(8.31)	(7.62)	(7.96)	(7.98)	(6.31)	(7.15)
S.Em.±	0.02	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.24(d): Residual effect of weed management and nutrient application on weed density at 30 DAS in succeeding wheat

Treatments	Weed density (No. m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management									
Weedy check	3.76	3.69	3.72	10.56	10.61	10.58	11.19	11.21	11.20
	(13.77)	(13.25)	(13.51)	(111.56)	(112.65)	(112.10)	(125.32)	(125.89)	(125.61)
Hand weeding 15 & 35 DAS	3.56	3.57	3.57	10.21	10.18	10.19	10.79	10.76	10.78
	(12.15)	(12.28)	(12.22)	(103.82)	(103.10)	(103.46)	(115.97)	(115.38)	(115.68)
Tembotrione	3.65	3.68	3.67	10.45	10.35	10.40	11.04	10.97	11.00
	(12.85)	(13.04)	(12.95)	(108.64)	(106.72)	(107.68)	(121.50)	(119.76)	(120.63)
Alachlor *fb* hand weeding	3.72	3.57	3.65	10.19	10.27	10.23	10.83	10.85	10.84
	(13.40)	(12.28)	(12.84)	(103.46)	(104.94)	(104.20)	(116.86)	(117.23)	(117.05)
Atrazine *fb* hand weeding	3.67	3.56	3.62	10.30	9.96	10.13	10.91	10.55	10.73
	(12.99)	(12.21)	(12.60)	(105.58)	(98.74)	(102.16)	(118.57)	(110.95)	(114.76)
Tembotrione *fb* hand weeding	3.64	3.65	3.65	10.26	10.06	10.16	10.86	10.68	10.77
	(12.80)	(12.86)	(12.83)	(104.76)	(100.75)	(102.75)	(117.56)	(113.60)	(115.58)
Alachlor+atrazine *fb* hand weeding	3.64	3.61	3.63	10.34	10.18	10.26	10.94	10.78	10.86
	(12.78)	(12.56)	(12.67)	(106.47)	(103.21)	(104.84)	(119.25)	(115.77)	(117.51)
Alachlor *fb* tembotrione	3.68	3.56	3.62	10.13	10.19	10.16	10.75	10.78	10.76
	(13.04)	(12.21)	(12.63)	(102.07)	(103.44)	(102.76)	(115.11)	(115.65)	(115.38)
Atrazine *fb* tembotrione	3.59	3.60	3.59	10.14	10.06	10.10	10.74	10.66	10.70
	(12.41)	(12.46)	(12.44)	(102.94)	(100.72)	(101.83)	(115.35)	(113.18)	(114.27)
S.Em. .±	0.07	0.08	0.03	0.18	0.16	0.09	0.17	0.18	0.08
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	3.64	3.60	3.62	10.25	10.16	10.21	10.86	10.76	10.81
	(12.79)	(12.53)	(12.66)	(104.69)	(102.91)	(103.80)	(117.47)	(115.44)	(116.46)
NPK+Zn	3.65	3.61	3.63	10.30	10.24	10.27	10.91	10.84	10.87
	(12.90)	(12.57)	(12.73)	(105.84)	(104.53)	(105.18)	(118.74)	(117.09)	(117.92)
NPKS+Zn	3.68	3.62	3.65	10.30	10.21	10.26	10.92	10.81	10.87
	(13.04)	(12.63)	(12.83)	(105.92)	(103.98)	(104.95)	(118.96)	(116.61)	(117.78)
S.Em.±	0.02	0.02	0.01	0.07	0.05	0.04	0.07	0.05	0.04
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 4.25: Residual effect of weed management and nutrient application on weed dry matter at 30 DAS in succeeding wheat

Treatments	Weed dry matter (g m^{-2})								
	Narrow-leaved weeds			Broad-leaved weeds			Total weeds		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management									
Weedy check	25.50	29.98	27.74	56.56	60.45	58.50	82.05	90.43	86.24
Hand weeding 15 & 35 DAS	25.20	29.59	27.40	57.46	61.44	59.45	82.66	91.03	86.85
Tembotrione	25.80	30.21	28.01	56.01	59.96	57.99	81.81	90.17	85.99
Alachlor *fb* hand weeding	25.99	30.42	28.20	54.89	58.81	56.85	80.88	89.23	85.05
Atrazine *fb* hand weeding	25.12	29.50	27.31	54.88	58.80	56.84	79.99	88.30	84.15
Tembotrione *fb* hand weeding	25.07	29.45	27.26	54.90	58.82	56.86	79.97	88.27	84.12
Alachlor+atrazine *fb* hand weeding	25.29	29.68	27.48	55.48	59.42	57.45	80.77	89.10	84.94
Alachlor *fb* tembotrione	25.77	30.18	27.97	54.67	58.59	56.63	80.44	88.77	84.60
Atrazine *fb* tembotrione	25.58	29.98	27.78	54.89	58.83	56.86	80.47	88.82	84.64
S.Em. ±	0.55	0.55	0.27	1.42	1.30	0.71	1.94	1.29	0.97
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
NPK	25.62	30.05	27.83	55.82	59.77	57.79	81.43	89.82	85.63
NPK+Zn	25.44	29.84	27.64	55.40	59.31	57.35	80.84	89.14	84.99
NPKS+Zn	25.38	29.78	27.58	55.36	59.30	57.33	80.74	89.07	84.91
S.Em.±	0.25	0.24	0.17	0.53	0.77	0.47	0.69	0.88	0.56
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.27: Residual effect of weed management and nutrient application on plant height and dry matter of succeeding wheat

Treatments	Plant height (cm)						Dry matter accumulation (g $plant^{-1}$)					
	30 DAS			At harvest			30 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Weed management												
Weedy check	11.44	11.46	11.45	91.73	91.98	91.86	11.76	12.35	12.05	297.08	297.96	297.52
Hand weeding 15 & 35 DAS	12.99	11.78	12.38	92.43	92.32	92.37	12.10	12.98	12.54	296.90	299.33	298.12
Tembotrione	12.94	13.06	13.00	93.00	91.95	92.48	12.35	12.26	12.30	298.01	298.51	298.26
Alachlor *fb* hand weeding	14.58	11.78	13.18	92.43	92.05	92.24	12.98	11.39	12.19	298.91	297.66	298.29
Atrazine *fb* hand weeding	13.00	13.06	13.03	92.01	92.57	92.29	12.28	12.51	12.40	298.98	300.22	299.60
Tembotrione *fb* hand weeding	11.44	11.94	11.69	92.07	92.58	92.32	12.50	11.65	12.08	297.45	297.13	297.29
Alachlor+atrazine *fb* hand weeding	14.20	12.14	13.17	93.23	91.78	92.51	12.90	11.52	12.21	297.50	299.55	298.53
Alachlor *fb* tembotrione	11.91	12.02	11.96	93.08	91.94	92.51	11.76	12.28	12.02	296.90	298.78	297.84
Atrazine *fb* tembotrione	13.55	13.18	13.36	92.71	91.86	92.28	12.10	12.55	12.33	297.08	299.18	298.13
S.Em. ±	0.73	0.89	0.36	0.51	0.32	0.25	0.56	0.54	0.28	5.35	3.49	2.67
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
NPK	12.93	12.16	12.55	92.71	91.94	92.32	12.24	12.31	12.27	297.71	298.37	298.04
NPK+Zn	12.66	12.40	12.53	92.45	92.15	92.30	12.37	12.19	12.28	297.58	299.13	298.36
NPKS+Zn	13.10	12.25	12.67	92.41	92.25	92.33	12.30	12.00	12.15	297.65	298.61	298.13
S.Em.±	0.25	0.23	0.17	0.34	0.15	0.18	0.20	0.21	0.14	2.36	1.80	1.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.28: Residual effect of weed management and nutrient application on yield attributes of succeeding wheat

Treatments	Yield attributes											
	Number of tillers metre^{-1} row length			Spike length (cm)			Number of grain spike^{-1}			1000-grain weight (g)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management												
Weedy check	101.63	101.85	101.74	10.40	11.50	10.95	28.59	28.00	28.30	38.60	39.18	38.89
Hand weeding 15 & 35 DAS	101.67	101.93	101.80	10.81	11.13	10.97	30.55	28.40	29.48	41.68	42.09	41.88
Tembotrione	101.92	102.03	101.97	10.44	10.28	10.36	29.39	30.27	29.83	41.27	41.87	41.57
Alachlor *fb* hand weeding	102.28	101.62	101.95	11.50	11.31	11.41	27.94	29.70	28.82	41.17	41.76	41.46
Atrazine *fb* hand weeding	102.25	101.85	102.05	11.02	11.11	11.06	28.00	29.24	28.62	41.11	41.70	41.40
Tembotrione *fb* hand weeding	101.56	102.20	101.88	11.04	10.42	10.73	28.70	31.11	29.90	41.61	42.20	41.91
Alachlor+atrazine *fb* hand weeding	103.06	101.93	102.49	11.13	10.72	10.93	28.59	29.37	28.98	40.36	40.96	40.66
Alachlor *fb* tembotrione	101.74	102.20	101.97	10.40	10.60	10.50	31.26	29.28	30.27	40.05	40.61	40.33
Atrazine *fb* tembotrione	102.25	101.85	102.05	10.81	10.58	10.70	29.44	30.34	29.89	42.01	42.61	42.31
S.Em. ±	1.27	0.79	0.63	0.33	0.39	0.17	1.02	1.04	0.51	1.00	1.17	0.50
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
NPK	101.82	101.86	101.84	11.00	10.98	10.99	29.28	29.24	29.26	40.65	41.04	40.84
NPK+Zn	102.06	101.79	101.92	10.76	10.78	10.77	28.85	29.78	29.32	41.08	41.70	41.39
NPKS+Zn	102.23	102.17	102.20	10.76	10.79	10.78	29.36	29.55	29.46	40.89	41.59	41.24
S.Em.±	0.64	0.43	0.38	0.18	0.20	0.13	0.31	0.31	0.22	0.43	0.40	0.29
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.29: Residual effect of weed management and nutrient application on yield and harvest index of succeeding wheat

Treatments	Yield (kg ha^{-1})									Harvest index (%)		
	Grain yield			Straw yield			Biological yield					
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Weed management												
Weedy check	3843	4167	4005	4646	4984	4815	8490	9151	8820	45.25	45.50	45.38
Hand weeding 15 & 35 DAS	3970	4199	4084	4822	4601	4711	8792	8799	8796	45.13	47.66	46.40
Tembotrione	4001	4365	4183	4857	4739	4798	8858	9104	8981	45.09	47.91	46.50
Alachlor *fb* hand weeding	4194	4202	4198	4781	4623	4702	8975	8825	8900	46.69	47.60	47.14
Atrazine *fb* hand weeding	4011	4288	4149	4793	4750	4772	8804	9038	8921	45.59	47.44	46.52
Tembotrione *fb* hand weeding	4089	4282	4186	4834	4636	4735	8923	8918	8921	45.80	47.97	46.88
Alachlor+atrazine *fb* hand weeding	4164	3843	4004	4899	4750	4824	9063	8593	8828	45.94	44.71	45.32
Alachlor *fb* tembotrione	4054	4266	4160	4917	4550	4733	8971	8816	8893	45.22	48.33	46.77
Atrazine *fb* tembotrione	3946	4152	4049	4800	4652	4726	8746	8804	8775	45.14	47.04	46.09
S.Em. ±	120	114	60	160	102	80	175	126	87	1.21	0.99	0.60
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
NPK	3991	4213	4102	4784	4656	4720	8776	8869	8822	45.45	47.47	46.46
NPK+Zn	4050	4172	4111	4888	4697	4793	8937	8869	8903	45.30	46.98	46.14
NPKS+Zn	4050	4203	4126	4778	4742	4760	8828	8945	8886	45.87	46.94	46.40
S.Em.±	52	54	37	43	42	30	67	66	47	0.38	0.40	0.28
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

5. DISCUSSION

In the preceding chapter, while presenting the results of the field experiment entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"**, significant variations in weed and crop characters were recorded on account of different treatments. In this chapter, efforts have been made to ascertain cause and effect relationship among the various parameters found significant on QPM. While doing so, references to the findings of previous works of similar fields have also been made to justify, support and substantiate the present findings.

5.1 Effect of weather

Statistical analysis of pooled data of the two years of experimentation for various characters indicated variations between years of investigation. The crop during first year produced 4072 kg ha^{-1} of mean QPM yield which was 93 kg ha^{-1} lower than the second year in spite of the fact that the two crops were grown under identical levels of management, resources and cultivation practices. The observed variations seem to be the result of environmental conditions (both edaphic and climatic), which might have influenced overall growth, development and crop yield. Profound effect of climatic conditions on productivity of crop is well established (Ahir *et al*., 2006, Schlenker, 2006).

Weather is a critical factor influencing the production of crops in any region. It is viewed by agronomists and meteorologists as a dominant climatic element influencing yield while economists look at the levels of technology and other measurable inputs (Paltasingh *et al.*, 2012). During the first year of experimentation, crop faced severe water stress at many instances during the crop growth period which is evident from lower rainfall of about 185 mm in the first year compared to the second year. In addition to the rainfall, variation in composition of the weed population and elements of different weather parameters recorded for two consecutive crop seasons (Table 3.1 a and b & Fig 3.1 and 3.2) *viz.,* temperature, relative humidity, sunshine hours and evaporation of the two crop seasons might have also influenced weed as well as crop growth in different manner and consequently variation in the crop yield.

5.2 Effect of weed management

5.2.1 Effect on weeds

5.2.1.1 Weed dynamics

All the weed management treatments in question caused significant reduction in weed density of narrow-leaved weeds, broad-leaved weeds and total weeds as well as their dry matter accumulation at various growth stages during both the years of study. The data showed that *Echinochloa colona* was most dominating weed at the experimental site during both the years. QPM was mainly infested with mixed flora of narrow and broad-leaved weeds *viz., Echinochloa colona* (L.) 29.5 %, *Cynodon dactylon* (L.) 6.5 %, *Cyperus rotundus* (L.) 6.3 %, *Dinebra retroflexa* (Vahl) Panz. 12.5 %, *Brachiaria reptans* (L.) 6.5 %, *Amaranthus viridis* (L.) 6.9 %, *Digera arvensis* (Forsk.) 7.0 %, *Trianthema portulacastrum* (L.) 14.8 % and *Commelina benghalensis* (L.) 10.0 % in weedy check at 60 DAS, respectively.

During both the years, atrazine *fb* tembotrione was found the most reducing the density and dry matter of all categories of weeds at all stages compared to other treatments. The pooled data of total weed density and dry matter at all successive stages indicated overall superiority of atrazine *fb* tembotrione followed by alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding (Table 4.1 a to 4.3 c).

Among all the herbicide treatments, atrazine *fb* tembotrione recorded the highest weed control efficiency of narrow-leaved weeds, broad-leaved weeds and total weeds (71.61, 72.51 and 72.07 %) followed by alachlor *fb* tembotrione (71.32, 72.45 and 71.88 %) and two hand weedings (71.27, 72.05 and 71.67 %). The possible reason might be due to the fact that performance of crop is directly proportional to the weed control efficiency. The higher weed control efficiency under these treatments could be attributed to the lower weed population and total weed dry matter as well. These results corroborated with the finding of Nadiger *et al.* (2013), Sanodiya *et al.* (2014), Swetha *et al.* (2015), Stanzen *et al.* (2016) and Rana *et al.* (2017).

The herbicide combination of atrazine *fb* tembotrione was more effective and had activity on a wide spectrum of weeds including grasses and broadleaf weeds in maize. This might be due to the fact that pre-emergence application of this herbicide checked the growth of majority of weeds checked for longer period possibly due to its longer persistence in soil and whatever the weeds left uncontrolled due to one or other reasons under the influence of this herbicide were effectively controlled by tembotrione applied at 20 DAS. Later on, the crop attained luxuriant growth with more height, number of leaves and dry matter in this treatment which ultimately controlled the weeds and protected the crop from their infestation. The results corroborated with the finding of Patel *et al.* (2006 a), Nadiger *et al.* (2013), Kumar and Jha (2015), Stanzen *et al.* (2016) and Rana *et al.* (2017).

Atrazine belongs to triazines group of herbicides which are widely known to inhibit growth of emerging seedlings. Injury symptoms appear a few days after seedling emergence. The primary atrazine sensitive site seems to be located within the chloroplast for resistant as well as susceptible plants. It inhibits the hill reaction and its associated noncyclic photophosphorylation while being ineffective against cyclic photophosphorylation (Richard *et al.*, 1969). Alachlor applied as pre-emergence inhibits seed germination by interfering with the metabolic activities *i.e.* inhibition of α-amylase and protease production induced by GA_3. The seedlings of annual grass species against which they are effective do not emerge following pre-emergence application (Rao, 2000). The result obtained in present study is in close agreement with the findings of Singh *et al.* (2007), Gopal *et al*. (2010), Sanodiya *et al.* (2014), Swetha *et al.* (2015) and Stanzen *et al.* (2016).

Tembotrione is currently registered as an important post-emergence herbicide for use in corn and has shown quite satisfactory results on weed control, particularly for grasses (Waddington and Young, 2006). As a member of the triketone family of active ingredients, tembotrione shows properties of a weak acid and HPPD (4-hydroxyphenylpyruvate dioxygenase) inhibitor. The inhibition of HPPD blocks the pathway of prenylquinone biosynthesis in plants. Early phytotoxicity symptoms are decreased levels of tocopherols and plastoquinone in the plant tissue and a reduced photosynthetic yield. Indirect inhibition of phytoene desaturase as an effect of blocked plastoquinone biosynthesis leads to a decrease in carotenoid levels particularly in young, still expanding leaves, cause typical foliar bleaching. The result corroborated with the finding of Singh *et al.* (2012 b), Idziak and Woznica (2014) and Rana *et al.* (2017).

Two hand weeding at 15 and 35 DAS removed the weeds completely and created condition more favourable for crop growth and ultimately resulted in the lowest density of later emerged weeds and their lowest biomass with higher weed control efficiency during the crop growth period. This might be due to the fact that removal of weeds manually twice in the field controlled early as well as late flushes of weeds up to the most critical stage of crop weed competition resulting in excellent performance of the crop compared to herbicides specially applied alone. The results corroborated with the findings of Malviya and Singh (2007), Sunitha *et al.* (2010), Choudhary *et al.* (2013), Deshmukh *et al.* (2014) and Shrinivas *et al.* (2015).

5.2.1.2 Nutrient uptake

Nutrient loss through uncontrolled weed growth throughout the crop season resulted in a loss of 63.22 kg N ha^{-1}, 11.88 kg P_2O_5 ha^{-1}, 78.80 kg K_2O ha^{-1} and 8.49 kg S ha^{-1} (Table 4.6 a & b). Reduction in weed biomass under different herbicide combinations and two hand weedings were accompanied by corresponding reduction in per hectare removal of N, P, K and S. The nutrient uptake by weeds is the function of per cent nutrient content and biomass, thus similar trend in uptake and total weed biomass production was an expected outcome. The nutrient depletion by weeds in the present study also substantiates this fact. The correlation studies (Table 5.1) indicate significant correlation between weed biomass and N, P, K and S uptake by weeds. The results corroborate with the findings of Sinha *et al.* (2005), Verma *et al*. (2006), Malviya and Singh (2007), Choudhary *et al.* (2013) and Owla *et al.* (2015).

5.2.2 Effect on crop

5.2.2.1 Growth parameters

Weed management treatments adopted during both the years of experimentation caused significant increase in all growth parameters of QPM *i.e.* plant height and crop dry matter accumulation at respective stages of observation compared to weedy check. Increase in overall growth of crop at all stages of observation was mainly due to significant reduction in weed competition, which otherwise would have interfered with the crop for incident solar radiation, nutrients and moisture. Competition for incidence photosynthetic phyton flux density (PPFD) in mixed maize communities is a major factor affecting crop yield (Tollenaar *et al.*, 1994).

The results of the investigation presented in previous chapter (Tables 4.8 to 4.11) reflect that various weed control treatments provided significant improvement in growth parameters of maize crop. Higher plant height and greater accumulation of dry matter by crop plants under weed control treatments is an indirect effect on account of least competition for plant growth inputs *viz.*, light, space, water and nutrients etc. Under reduced density and dry matter of weeds, plants get sufficient space for optimum expansion of leaves and branches as early as possible (Gupta, 2012). Thus, under least crop-weed competition, adequate availability of light, optimum temperature, space along with improvement in physiological and morphological characters of the plants can be reasoned for greater photosynthetic rate and thereby more accumulation of dry matter (Duncan, 1971 and Korpff, 1993). This is well established by presence of significant negative correlation between crop and weed dry matter at successive growth stages (Table 5.1).

All weed control measures increased growth parameters of crop at successive stages over weedy check. Among the treatments, atrazine *fb* tembotrione recorded the maximum growth characters followed by alachlor *fb* tembotrione and two hand weeding. The superiority of these treatments was because of better control of all categories of weeds which resulted in reduced weed competition with crop. Results so obtained are in close conformity with the finding of Singh *et al*. (2007), Singh *et al*. (2009 b), Rao *et al*. (2009), Verma *et al.* (2009) and Barad *et al.* (2015).

In general, the aforesaid improvements seems to be on account of direct impact of different weed management treatments through least crop-weed competition whereas, indirect effect might be least competition for plant growth inputs *viz.*, light, space, water, nutrients etc. Similarly, under reduced density and dry matter of weeds, crop plants get sufficient space for optimum expansion of leaves as early as possible.

5.2.2.2 Yield attributes and yield

Economic yield is a function of dry matter accumulation, efficiency to translocate photosynthates from assimilatory area to sink to accumulate in different plant parts and ultimately on yield attributing traits.

During both the years as well as on pooled basis, experimental results showed that all the weed management treatments significantly influenced all the growth and related parameters compared to weedy check, which in turn increased all the yield attributes *viz.*, grains cob^{-1}, weight of grains plant^{-1}, test weight and shelling per cent (Table 4.13 & 4.14) which ultimately reflected into significantly higher grain, stover and biological yields. The highest yield attributing characters *viz.*, grains cob^{-1}, weight of grain $plant^{-1}$ and test weight were recorded under atrazine *fb* tembotrione followed by alachlor *fb* tembotrione and two hand weedings at 15 and 35 DAS. This can be attributed to the lowest infestation of weeds which resulted in higher weed control efficiency and lesser nutrient drain together with lesser degree of competition for other growth resources (moisture, space and light). Weed management practices reduced the weed infestation and create condition more favourable for crop. Patel *et al.* (2006 c), Sharma and Gautam (2010), El-Metwally *et al.* (2012), Deshmukh *et al.* (2014), Owla *et al.* (2015), Kour *et al.* (2016) and Rana *et al.* (2017) also reported similar results.

The better expression of yield attributes in herbicides treated and manually weeded plots might be due to poor resurgence frequency and growth of weeds in these treatments. Hence, weeds were unable to compete with the crop plants for different growth factors. Improvement in yield attributes occurred when weeds were controlled in the early growth stages particularly during critical growth period either manually or chemically, which brought down competition and created congenial micro-environment for better establishment and growth of the crop. By controlling weeds with the use of different measures significantly higher grain, stover and biological yields were recorded during both the years of investigation (Table 4.15). Atrazine *fb* tembotrione followed by alachlor *fb* tembotrione and two hand weedings were found significantly superior in this regard. The increased grain, stover and biological yields were obviously the results of better weed management which rendered favorable condition like increased availability of nutrient, moisture, light and other factors to the crop plant, which resulted in better growth and higher dry matter production of plants. Enhanced values of yield attributing characters were the outcome of these effects.

Correlation coefficient between grain yield and dry matter accumulation at harvest, grains cob^{-1}, weight of grains $plant^{-1}$ and test weight (r=0.795**, r=0.847**, r=0.969** and r=0.832**, respectively) validate profound effects of these parameters on yield. The increase in grain yield could also be due to reduced uptake of nutrients by weeds. Negative correlation of grain yield with uptake of nutrients by weeds explains the cause for increased grain yield. Reduction in weed dry matter production under various weed management treatments were accompanied by reductions in per hectare removal of nutrients by weeds. The yield was significantly improved by two hand weedings and combination of atrazine and alachlor with tembotrione or hand weeding over weedy check. By applying these treatments, reduced weed dry matter accumulation was observed which resulted in to increase yield attributes and consequently grain yield of maize (Singh *et al*., 2007). The improvement in yield with these treatments have also been reported by Patel *et al*. (2006 a), Walia *et al*. (2007), Prasad *et al*. (2008) and Changsaluk *et al.* (2009), Choudhary *et al*. (2013) and Owla *et al*. (2015).

Alike grain and stover yields, biological yield also significantly increased under various treatments of weed management over weedy check (Table 4.15). Increase in these yields might be due to the direct influence of reduced weed competition which in turn resulted in higher dry matter accumulation as a consequence of higher nutrient uptake by the crop. The results so obtained for stover and biological yield corroborate with the findings of Patel *et al*. (2006 c), Singh *et. al.* (2012 b), Choudhary *et al*. (2013) and Owla *et al*. (2015).

5.2.2.3 Nutrient content, uptake and quality

The results showed that all weed control treatments caused significant increase in N, P, K and S content in grain compared to weedy check. Likewise, protein content in grain with these treatments also significantly increased, as protein content is solely function of nitrogen content. Similar results were also reported by Patel *et al*. (2006 b), Malviya *et al.* (2012) and Choudhary *et al*. (2013).

Weed management practices improved the nutrient uptake by grain and stover of crop significantly compared to weedy check (Tables 4.18 a to d). The highest N uptake resulted with two hand weedings and P, K and S uptake by the crop was recorded with atrazine *fb* tembotrione followed by alachlor *fb* tembotrione and two hand weedings, which might be ascribed to higher yield under these treatments as uptake of nutrient is the function of crop yield and nutrient concentration. Decreased crop weed competition concurrently increased nutrient availability, resulted in better crop growth and higher crop biomass production coupled with more nutrient content. In the present study, positive and significant correlation between grain yield and their N, P, K and S uptake by grain (r=0.972**, r=0.996**, r=0.989** and r=0.970**, respectively) further substantiate the fact. These results corroborate with the findings of Sharana *et al.* (2005), Sinha *et al.* (2005), Patel *et al*. (2006 b) and Choudhary *et al.* (2013).

5.3.2.4 Economics

A minimum net monetary return was fetched under weedy check plots as a result of the lowest grain and stover yields (Table 4.23). However, pre-emergence application of atrazine with post-emergence application of tembotrione was found most remunerative, as it fetched the highest net return (₹ 70254 ha^{-1}) and B:C ratio (2.74). The low investment under different herbicide application coupled with good economic yield might be the reason for higher net monetary return and B:C ratio. Two hand weedings gave maximum gross monetary return but B:C ratio was lower due to higher variable cost for weed management. Similar findings were also reported by Kamble *et al.* (2005), Rao *et al*. (2009), Sunitha *et al.* (2010)**,** Choudhary *et al.* (2013), Owla *et al.* (2015) and Swetha *et al.* (2015).

5.3 Effect of nutrient management

5.3.1 Effect on weeds

Varying nutrient management treatments failed to affect the weed density (Tables 4.1 a to 4.2 d) as well as nutrient content and uptake (except S) (Tables 4.5, 4.6 a & b) while weed dry matter was significantly affected by different nutrients (Tables 4.3 a to c) in either of the years as well as in pooled analysis. Higher uptake of S by weeds under various nutrient management treatments might be attributed to higher nutrient content because nutrient uptake is product of nutrient content and its biomass. Thus, similarity in the trend of uptake was an expected outcome. However, weed biomass was not affected significantly under different nutrient management treatments. Profound effect of different nutrient management treatments on nutrient uptake by weeds has also been reported by Choudhary *et al.* (2013) and Owla *et al.* (2015).

5.3.2 Effect on crop

5.3.2.1Growth parameters

It is evident from the results that application of NPK+Zn and NPKS+Zn significantly improved various growth parameters, *viz*., plant height and dry matter at successive growth stages compared to NPK. The concomitant effect of these improvements ultimately led to production of higher biomass by plants at harvest.

Under present investigation the preponderant effect of application of NPK+Zn and NPKS+Zn on various growth parameters of QPM appears to be on account of enrichment of soil with N, P, K, S and Zn nutrients to the level of sufficiency. These improvements might have contributed to higher root growth and its proliferation to help in better uptake of required nutrient from soil. The significant improvement in nutrient status of plant parts (grain and stover) resulted from better availability of nutrients for growth and development of the plant right from early stage. The nutrients are harvestable plant part and are mostly translocated from vegetative to reproductive parts. Thus better nutritional environment in plants under the influence of NPK+Zn and NPKS+Zn seems to have promoted height of plants and growth of individual leaf by way of active cell division, and their elongation. The larger canopy development and plant height could be reason for increased interception, absorption and utilization of radiant energy which in turn increased overall growth and finally dry matter at successive growth stages. These results are in accordance with the findings of Verma *et al*. (2006), Singh *et al*. (2009 a), Tetarwal *et al*. (2011), Gul *et al.* (2015) and Joshi *et al.* (2016).

5.3.2.2 Yield attributes and yield

The nutrient management treatments NPK, NPK+Zn and NPKS+Zn were statistically comparable in increasing the yield and yield attributing parameters of QPM during both the years of experimentation (Tables 4.13 to 4.15).

Crop grain yield is negatively correlated with weed dry matter and positively correlated with growth and yield attributes (Table 5.1). Application of nutrients increases availability of metabolites which in turn has a role to play in improvement of yield attributes and there by the yield. The results obtained here are in close conformity with findings of Kumar *et al.* (2002), Sutalia and Singh (2005), Singh *et al*. (2009 a), Om *et al.* (2014), Gul *et al.* (2015) and Joshi *et al.* (2016).

The prepondent effect of balanced fertilization appears to be due to vigrous growth of individual plant as reflected through increased plant height and dry matter of crop. Furthermore, in preceding text, it was well emphasized that balanced fertilization plays a vital role in improving nutritional status of plants at harvest in both grain and stover. These improvements suggest greater availability of metabolites and nutrients synchronized to demand for growth and development of each reproductive structure. Due to indeterminate growth characteristics of QPM plant *viz*. slow initial growth and later on vigorous growth of crop (Singh, 2010), it has been widely assumed that both vegetative and reproductive development of plant compete with each other for the nutrients and metabolites. Thus higher availability of both these inputs as evinced from greater crop growth and nutrients accumulation particularly at later growth stage under balanced fertilization clearly demonstrate reduced competition between developing structures consequently improving magnitude along with the functional activity of each reproductive structure.

Significant increase in grain and stover yields due to application of NPKS+Zn could be ascribed to the fact that yield of the crop is a function of several yield components. The positive correlation between grain yield and various yield components *i.e*. grains cob^{-1} (r = 0.847), grain weight plant^{-1} (r = 0.969) and test weight (r = 0.832) also affirmed the role of yield attributes in improving grain yield of maize.

The significant increase in stover yield with application of balanced fertilization seems to be due to its direct influence on dry matter production at successive stages by virtue of increased photosynthetic efficiency. While indirect influence seems to be due to increase in plant height. Further, biological yield is a function of grain and stover yield representing reproductive and vegetative growth of the crop. Increased photosynthesis efficiency and nutrient accumulation due to balanced fertilization might have ultimately led to production of higher biological yield under its application. The results of present investigation indicated higher production of maize under influence of balanced fertilization and these are in close conformity with findings of Verma *et al*. (2006), Srikanth *et al.* (2009), Behera and Singh (2010), Paramasivan *et al.* (2011), Jena *et al.* (2013), Paramesh *et al.* (2014), Gul and Khanday (2015) and Joshi *et al.* (2016).

5.3.2.3 Nutrient content, uptake and quality

The results of plant analysis (Tables 4.17 a & b) revealed that application of various nutrients improved concentration of nutrients (N, P, K and S) in grain as well as stover (except K). Alike concentration, the uptake of these nutrients also showed positive influence under various nutrients. The highest nutrient uptake was registered with the application of NPKS+Zn (Tables 4.18 a to d).

The marked improvement in nutritional status of grain and stover could be ascribed to their greater availability in soil environment along with extraction and translocation towards plant system. It is generally believed that in plant system, extracted nutrients are used for maintaining their critical concentration, which can be used for growth of developing structures. Thus greater availability of nutrients with balanced fertilization seems to have synergistic interactions between these nutrients which maintained critical concentration at cellular level, fulfilled their requirements for profuse plant growth and their efficient translocation towards sink component. It is an established fact that nutrient accumulation depends upon dry matter accumulation and concentration of nutrient at cellular level. The concomitant improvement in both of these components reflected higher accumulation of nutrients with balanced fertilization. The results are in close conformity with the findings of Totawat *et al*. (2001), Sutalia and Singh (2005), Verma *et al*. (2006), Singh and Yadav (2007), Behera and Singh (2009), Tetarwal *et al*. (2011) and Manea *et al.* (2015).

It is evident from results that application of NPKS+Zn significantly improved the protein content in grain over NPK during both the years of study (Table 4.16). The improvement in protein under the influence of nutrients seems to be on account of increased nitrogen content of grain. The supply of nitrogen is related to the utilization of carbohydrate and formation of protein. Adequate supply of nitrogen developed conditions which are favourable for formation of proteins from the manufactured carbohydrates that are deposited in vegetative portion of the plant. It is well known that nitrogen constitutes 16 per cent of the protein (FAO Food and Nutrition Paper 77, 2003). The correlation studies (Table 5.1) also affirmed profound influence of nitrogen content of grain and protein content ($r = 1.000^{**}$). Increased protein content with increasing nutrients are in close conformity with the findings of Misra *et al.* (2001) and Balai *et al.* (2011).

5.3.2.4 Economics

Application of different nutrient management treatments also increased the net return and B:C of QPM (Table 4.24). Application of NPKS+Zn gave significantly higher net return (₹ 64862 ha^{-1}) while B:C ratio (2.48) remain highest with NPK.

Increase in net realization might be due to increase in grain yield under NPKS+Zn. This is in accordance with the findings of Sahoo and Mahapatra (2007), Choudhary *et al*. (2012) and Verma *et al.* (2012).

Table 5.1 Correlation coefficient (r) and regression equation (Y= a+bX) between various crop parameters (Based on mean of two years)

S. No.	Dependent variable (Y)	Independent variable (X)	Correlation coefficient (r)	Regression equation (Y = a + b X)
1	Crop DMA (g $plant^{-1}$) at harvest	Plant height at harvest (cm)	0.833**	Y = 51.191 + 0.702 X
2	Crop DMA (g $plant^{-1}$)at 30 DAS	Total weed dry matter (g m^{-2}) at 30 DAS	-0.841**	Y = 28.551 – 0.188 X
3	Crop DMA (g $plant^{-1}$) at 60 DAS	Total weed dry matter (g m^{-2}) at 60 DAS	-0.773**	Y = 86.085 – 0.434 X
4	Crop DMA (g $plant^{-1}$) at harvest	Total weed dry matter (g m^{-2}) at harvest	-0.665*	Y = 200.585 – 0.088 X
5	Grain yield (kg ha^{-1})	Crop DMA (g $plant^{-1}$) at 30 DAS	0.922**	Y = 1749.329 + 107.745 X
6	Grain yield (kg ha^{-1})	Crop DMA (g $plant^{-1}$) at 60 DAS	0.920**	Y = -2689.625 + 90.767 X
7	Grain yield (kg ha^{-1})	Crop DMA (g $plant^{-1}$) at harvest	0.795**	Y = -1813.043 + 32.031 X
8	Grain yield (kg ha^{-1})	No. of grains cob^{-1}	0.847**	Y = -766.496 + 15.062 X
9	Grain yield (kg ha^{-1})	weight of grain $plant^{-1}$	0.969**	Y = -798.254 + 65.775 X
10	Grain yield (kg ha^{-1})	Test weight	0.832**	Y = -904.153 + 26.770 X
11	Grain yield (kg ha^{-1})	Total weed dry matter (g m^{-2}) at 30 DAS	-0.944**	Y = 4980.281 – 24.73 X
12	Grain yield (kg ha^{-1})	Total weed dry matter (g m^{-2}) at 60 DAS	-0.931**	Y = 5434.75 – 8.630 X
13	Grain yield (kg ha^{-1})	Total weed dry matter (g m^{-2}) at harvest	-0.927**	Y = 4984.191 – 4.950 X
14	Grain yield (kg ha^{-1})	Total N uptake by crop (kg ha^{-1})	0.972**	Y = 849.019 + 25.175 X
15	Grain yield (kg ha^{-1})	Total P uptake by crop (kg ha^{-1})	0.996**	Y = 1047.642 + 100.20 X
16	Grain yield (kg ha^{-1})	Total K uptake by crop (kg ha^{-1})	0.989**	Y = -42.173 + 35.366 X
17	Grain yield (kg ha^{-1})	Total S uptake by crop (kg ha^{-1})	0.970**	Y = 801.413 + 151.905 X
18	Grain yield (kg ha^{-1})	Total N uptake by weeds (kg ha^{-1})	-0.923**	Y = 4979.432 – 37.254 X
19	Grain yield (kg ha^{-1})	Total P uptake by weeds (kg ha^{-1})	-0.927**	Y = 4947.419 – 196.09 X
20	Grain yield (kg ha^{-1})	Total K uptake by weeds (kg ha^{-1})	-0.926**	Y = 4977.45 – 29.912 X
21	Grain yield (kg ha^{-1})	Total S uptake by weeds (kg ha^{-1})	-0.929**	Y = 4958.294 – 276.083 X
22	Total N uptake by crop (kg ha^{-1})	Total N uptake by weeds (kg ha^{-1})	-0.842**	Y = 160.17 – 1.311 X
23	Total P uptake by crop (kg ha^{-1})	Total P uptake by weeds (kg ha^{-1})	-0.927**	Y = 38.883 – 1.948 X
24	Total K uptake by crop (kg ha^{-1})	Total K uptake by weeds (kg ha^{-1})	-0.935**	Y = 141.918 – 0.845 X
25	Total S uptake by crop (kg ha^{-1})	Total S uptake by weeds (kg ha^{-1})	-0.875**	Y = 26.892 – 1.662 X
26	Protein content	N content (%) in grain	1.000**	Y = 0.026 – 6.235 X

** Significant at 1% level of significance

6. SUMMARY

The results of the field experiment entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** conducted during *kharif* and *rabi* seasons of 2015-16 and 2016-17 presented and discussed in the preceding chapters are summarized as under:

6.1 EFFECT OF WEED MANAGEMENT

6.1.1 Weeds

- In two years of field study, QPM was mainly infested with mixed flora of narrow and broad-leaved weeds *viz., Echinochloa colona* (L.), *Cynodon dactylon* (L.), *Cyperus rotundus* (L.), *Dinebra retroflexa* (Vahl) Panz., *Brachiaria reptans* (L.), *Amaranthus viridis* (L.), *Digera arvensis* (Forsk.), *Trianthema portulacastrum* (L.) and *Commelina benghalensis* (L.).

- At 30 days stage of observation application of atrazine *fb* tembotrione significantly reduced the density of narrow-leaved (5.02/ 4.87/ 4.94 $m^{-2)}$, broad-leaved (5.29/ 4.95/ 5.12 $m^{-2)}$ and total weeds (7.26/ 6.90/ 7.08 m^{-2}) during both the years and on pooled basis over weedy check.

- Application of atrazine *fb* tembotrione at 60 DAS resulted in the lowest density of narrow-leaved and total weeds while broad-leaved weeds were lowest with two hand weedings during first year and pooled basis. On pooled basis, atrazine *fb* tembotrione accounted for 82.05 and 77.43 per cent reduction in density of narrow-leaved and total weeds, respectively whereas broad-leaved weeds density reduced by 70.19 per cent with two hand weedings compared to weedy check.

- At 30 and 60 DAS and at harvest, minimum dry matter of both narrow-leaved and broad-leaved weeds was recorded under application of atrazine *fb* tembotrione. The next treatment in the order of superiority was alachlor *fb* tembotrione and two hand weedings. On pooled basis, atrazine *fb* tembotrione observed 74.66, 64.67 and 72.06 per cent decrease in total dry matter of weeds at 30, 60 DAS and at harvest, respectively.

- On pooled basis, maximum weed control efficiency was recorded with atrazine *fb* tembotrione (72.07 %) closely followed by alachlor *fb* tembotrione (71.88 %) and two hand weeding (71.67 %).
- Different weed management treatments had no significant effect on N, P, K and S content in weeds at harvest. However, significant decrease in total N, P, K and S uptake by weeds were recorded with all weed management treatments compared to weedy check. Application of atrazine *fb* tembotrione recorded significantly lower N, P, K and S uptake by weeds over weedy check.

6.1.2 Crop

- Various weed management treatment failed to cause any significant variation in plant population at 30 DAS and at harvest during both the years of study as well as on pooled basis.
- At harvest, maximum plant height (209.1 and 212.2 cm) was recorded under atrazine *fb* tembotrione during both the years closely followed by alachlor *fb* tembotrione (207.4 and 210.6 cm) and two hand weedings (204.9 and 208.7 cm).
- Weed management treatments either herbicides or hand weeding significantly increased dry matter accumulation by the crop as compared to weedy check in either of the years. On pooled basis, significantly higher dry matter accumulation at 30 and 60 DAS were recorded under atrazine *fb* tembotrione (27.24 and 83.02 g plant^{-1}, respectively) while at harvest crop dry matter was highest with alachlor *fb* tembotrione (199.81 g plant^{-1}).
- Yield attributing characters *viz.*, grains cob^{-1}, weight of grains, test weight and shelling per cent were significantly influenced by various weed management treatments compared to weedy check while days to 50% silking and number of cobs plant^{-1} remained unaffected by different weed management treatments. On pooled basis, atrazine *fb* tembotrione recorded the highest values of yield attributes *viz.*, grains cob^{-1} (367.91), weight of grains (82.79 g), test weight (212.03 g) and shelling per cent (76.58 %) followed by alachlor *fb* tembotrione and two hand weedings.
- All weed management treatments significantly increased grain yield of QPM during both the years. The mean data indicated that atrazine *fb* tembotrione

achieved maximum grain yield followed by two hand weedings and alachlor *fb* tembotrione. However, these treatments were found statistically at par with each other. Application of alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding significantly increased grain yield compared to both tembotrione alone and tembotrione *fb* hand weeding. The range of yield enhancement due to different weed control treatments was 53.8 to 71.8 per cent over weedy check. On pooled basis, increase in grain yield with application of atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings were 71.8, 71.1 and 71.2 per cent, respectively over weedy check. While, yields due to application of alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding were higher by 64.2, 63.2 and 59.0 per cent over weedy check, respectively.

- Likewise, hand weeding and application of herbicides alone, in combination with hand weeding and in sequence resulted in significantly higher stover and biological yields over weedy check during both the years. Atrazine *fb* tembotrione resulted in the highest stover and biological yield followed by alachlor *fb* tembotrione, two hand weedings, alachlor+atrazine *fb* hand weeding, atrazine *fb* hand weeding and alachlor *fb* hand weeding.

- Different weed management treatments had no significant effect on harvest index of QPM.

- Various weed management treatments significantly increased N, P, K and S content of QPM in grain and stover (except K) over weedy check. Further, significantly higher N, P, K and S uptake by crop was observed compared to weedy check under various weed management treatments.

- Two hand weedings resulted in maximum protein content in grain (12.04 %) and chlorophlyll content at 30 DAS (1.883 mg g^{-1}), whereas, at 60 DAS, chlorophlyll content was maximum with atrazine *fb* tembotrione (1.913 mg g^{-1}).

- On pooled basis, the highest net return and B:C was obtained under atrazine *fb* tembotrione with corresponding values of ₹ 70254 ha^{-1} and 2.74.

- All weed management treatments did not differ for soil pH, EC, organic carbon and available nitrogen, phosphorus, potassium and sulphur status of soil at harvest of the crop.

6.2 EFFECT OF NUTRIENT MANAGEMENT

6.2.1 Weeds

- Different nutrient management treatments had no significant effect on weed density while weed dry matter was significantly affected by different nutrients in either of the years as well as on pooled basis.
- Nutrient management failed to exhibit significant effect on N, P and K content in weeds at harvest. Further N, P and K uptake by weeds didn't significantly increase due to different nutrient management treatments.

6.2.2 Crop

- Different nutrients had no significant effect on plant population at 30 DAS and at harvest.
- Application of different nutrient management treatments significantly increased plant height at 30 DAS and at harvest. On pooled basis, maximum plant height at 30 DAS and at harvest was recorded under application of NPKS+Zn.
- Application of NPKS+Zn significantly increased dry matter accumulation over NPK at all stages of crop growth.
- Nutrient application of NPKS+Zn resulted in significant improvement in yield attributes *viz.*, number of grains cob^{-1}, weight of grain, test weight and shelling per cent while days to 50% silking and number of cobs plant^{-1} remained unaffected by different nutrient management treatments.
- Across the years, different nutrient management treatments resulted in increased affected the grain, stover and biological yield of QPM. On pooled basis, maximum grain (4275 kg ha^{-1}), stover (7227 kg ha^{-1}) and biological (11502 kg ha^{-1}) yields were recorded under the application of NPKS+Zn which increased grain, stover and biological yield by 7.5, 7.2 and 7.3 per cent, respectively over NPK.

- Application of different nutrient management treatments significantly increased N, P, K and S content in grain and stover (except K). On pooled basis, maximum N, P, K and S content in grain and stover (except K) was recorded with the application of NPKS+Zn. Similarly, application of NPKS+Zn registered the highest total N (136.33 kg ha^{-1}), P (32.11 kg ha^{-1}), K (122.55 kg ha^{-1}) and S (23.21 kg ha^{-1}) uptake on pooled basis.

- During both the years, significant increase was registered in protein content in grain at harvest and chlorophyll content at 30 and 60 DAS under the application of NPKS+Zn. On pooled basis, maximum protein content in grain at harvest (11.41 %) and chlorophyll content at 30 and 60 DAS (1.816 and 1.88 mg g^{-1}) was recorded under application of NPKS+Zn.

- On pooled basis, application of NPKS+Zn recorded significantly higher net return of ₹ 64862 ha^{-1} while maximum B:C ratio (2.48) was recorded with NPK among different nutrient management treatments.

- Soil pH, EC and organic carbon at harvest of QPM were found unaffected with various nutrient management treatments. Further, different nutrient management treatments failed to cause any significant effect on available nitrogen, phosphorus, potassium and sulphur nutrients in soil at harvest as well as soil enzyme dehydrogenase, phosphatase and urease activity at harvest of QPM.

6.3 RESIDUAL STUDIES

- Under residual study on succeeding wheat, no significant effect of weed and nutrient management treatments applied in maize crop was observed on weed density and dry matter in wheat as well as plant height, dry matter accumulation, yield parameters (*viz.*, number of tillers $metre^{-1}$ row length, spike length, number of grain $spike^{-1}$ and 1000-grain weight), grain, straw, biological yield and harvest index of wheat during both the years of experimentation.

7. CONCLUSION

Two years investigation on Quality Protein Maize that weed management by atrazine *fb* tembotrione resulted in the highest weed control efficiency (72.07 %), grain yield (4516 kg ha^{-1}), maximum net return (₹ 70254 ha^{-1}) and B:C ratio (2.74).under nutrient management, conjoint application of 120 kg N + 60 kg P_2O_5 + 30 kg K_2O along with 40 kg S and 5 kg Zn ha^{-1} resulted in highest grain yield (4275 kg ha^{-1}) and net return (₹ 64862 ha^{-1}) whereas maximum B:C ratio (2.48) was recorded with NPK.

It is recommended that weeds in quality protein maize should be controlled by application of atrazine 0.5 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS and soil should be fertilized with additional application of sulphur at 40 kg ha^{-1} and zinc at 5 kg ha^{-1} with recommended dose of N_{120} P_{60} K_{30}.

LITERATURE CITED

Abouziena, H.F., El-Karmany, M.F., Sing, M. and Sharma, S.D. 2007. Effect of nitrogen rates and weed control treatments on maize yield and associated weeds in sandy soils. *Weed Technology* **21**: 1049 – 1053.

Abouziena, H.F., El-Metwally, I.M. and El-Desoki, E.R. 2008. Effect of plant spacing and weed control treatments on maize yield and associated weeds in sandy soils. *American-Eurasian Journal of Agricultural and Environmental Sciences* **4:** 9-17.

Ahir, I.S.A.T., Akata, N.N., Li, A.M.A., Ustafa, H.M.M., Aad, A.S.I.S., Akata, K.T., Shikawa, O.S.A. and Bdalla, O.S.A. 2006. Genotypic and temperature effects on wheat grain yield and quality in a hot irrigated environment. *Plant Breeding* **125**: 323-330.

Ahlawat, I.P.S., Gangaiah, B. and Singh, O.M. 2005. Effect of fertilizer and stover management on productivity and soil fertility in chickpea (*Cicer arietinum*) - maize (*Zea mays*) cropping system. *Indian Journal of Agricultural Sciences* **75**: 400-403.

Arnon, D.I. 1949. Copper enzyme in isolated chloroplast poly-phenoloxide in *Beta vulgaris. Plant Physiology* **24**: 1-15.

Balai, M.L., Verma, A., Nepalia, V. and Kanthaliya, P.C. 2011. Productivity and quality of maize (*Zea mays)* as influenced by integrated nutrient management under continuous cropping and fertilization. *Indian Journal of Agricultural Sciences* **81**: 374-376.

Barad B., Mathukia, R.K., Gohil, B.S. and Chhodavadia, S.K. 2015. Intrgrated weed management in popcorn. *In*: 25th Asian-Pacific Weed Science Society Conference on *"Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during 13-16 October: pp. 270.

Behera, S.K. and Singh, D. 2009. Effect of 31 years of continuous cropping and fertilizer use on soil properties and uptake of micronutrients by maize (*Zea mays*)-wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Sciences* **79**: 264-267.

Behera, S.K. and Singh, D. 2010. Impact of continuous fertilizer use on fractions of manganese in soil and their contribution to availability and its uptake by maize

(*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **80:** 316–320.

Bijanzadeh, E. and Ghardiri, H. 2006. Effect of separate and combined treatments of herbicides on weed control and corn (*Zea mays* L.) yield. *Weed Technology* **20**: 640-645.

Birgani, D.G., Afarinesh, A. and Zand, E. 2010. Evaluation of efficacy of time and rate of application of metribuzin on weeds of corn (Persian). *In*. Proceeding of 3rd Iranian Weed Science Congress, Volume 1: Weed biology and ecophysiology, Babolsar, Iran, Iranian Society of Weed Science, Tehran, Iran, 17-18 February 2010. pp. 349-352.

Black, C.A. 1965. Methods of soil analysis. Part I and II. American Society of Agronomy, Madison Wisconsin, USA.

Bontempo, A.F., Carneiro, G.D., Guimarães, F.A., Dos, R.M.R., Silva, D.V., Rocha, B.H., Souza, M.F. and Sediyama, T. 2016. Residual tembotrione and atrazine in carrot. *Journal of Environmental Science & Health Part B* 51(7): 465-468.

Bouyoucos, 1962. Hydrometer method for making particle size analysis of soil. *Agronomy Journal* **55**: 464-465.

Brady, N.C. 1983. The Nature and Properties of Soils. Mac Millan Publishing Company, New York and Collier Mac Millan Publishers, London, pp: 750.

Casida, L.E., Klein, D.A. and Santoro, T. 1964. Soil dehydrogenase activity. *Soil Science* **98**: 371-376.

Cerrudo, D., Page, E.R., Tollenaar, M., Stewart, G. and Swanton, C.J. 2012. Mechanism of yield loss in maize caused by weed competition. *Weed Science* **60** (2): 225-232.

Changsaluk, S., Pornprom, T. , Waramitr, N., Suwanmonkha, R. and Lim-Arooim, S. 2009. Weed control in sweet corn and field corn. Proceedings of the 47th Kasetsart University Annual Conference, 17-20 March, 2009. Subject: Plants and Agricultural Extension and Communication. pp: 351-360.

Chaudhary, S.U., Hussian, M. and Ali, M.A. 2008. Effect of weed competition period on yield and yield components of wheat. *Journal of Agricultural Research* **46**: 47-53.

Chesnin, L. and Yien, C.H. 1950. Turbidimetric determination of available sulphates. *Soil Science Society American Proc*. **15**: 149-151.

Chikoye, D., Ellis-Jones J., Patrick K., Udensi E.U., Simon E.I., Ter Rumun A. 2006. Options for cogongrass *(Imperata cylindrica)* control in white Guinea yam *(Dioscorea rotundata)* and cassava *(Manihot esculenta). Weed Technology* **20**: 784-792.

Chikutuma, M., Lovejoy, T. and Wisdom, K. 2015. The effect of herbicides on residual effects of atrazine under conservation agriculture. *Greener Journal of Agricultural Sciences*.

Choudhary, P., Nepalia, V. and Singh, D. 2013. Effect of weed control and sulphur on productivity of quality protein maize *(Zea mays)*, dynamics of associated weeds and relative nutrient uptake. *Indian Journal of Agronomy* **58**(4): 534-538.

Choudhary, R., Singh, D., Nepalia, V. and Choudhari, R. 2012. Enhancement of productivity of quality protein maize through N and sulphur fertilization under sub-tropical condition. *In*: Extended Summaries Vol. 3: 3rd International Agronomy Congress: Agriculture Diversification, Climate Change Management and Livelihoods, Nov. 26-30, 2012, Indian Society of Agronomy, New Delhi. pp. 1242-43.

Cocharan, W.G. and Cox, G.M. 1967. Experimental designs. 2nd edition, John Willey and Sons Inc., New York.

Dadarwal, R.S., Jain, N.K., and Singh, D. 2009. Integrated nutrient management in baby corn (*Zea mays* L.). *Indian Journal of Agricultural Sciences* **79**: 1023-1025.

Das, A., Patel, D.P., Munda, G.C. and Ghosh, P.K. 2010. Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and soil fertility of maize (*Zea mays*) - mustard (*Brassica campestris*) cropping system. *Indian Journal of Agricultural Sciences* **80**: 85-88.

Dass, S., Kumar, A., Jat, S.L., Parihar, C.M., Singh, A.K., Chikkappa, G.K. and Jat, M.L. 2012. Maize holds potential for diversification and livelihood security. *Indian Journal of Agronomy* **57** (3rd IAC Special Issue): 32–37.

Damalas, C.A., Dhima, K.V. and Eleftherohorinos, I.G. 2004. Bispyribac - sodium efficacy on early watergrass (*Echinochloa oryzoides*) and late water grass (*Echinochloa phyllopogon*) as affected by co-application of selected rice herbicides and insecticides. *Weed Technology* **22**: 622-627.

Deshmukh, J.P., Shingrup, P.V., Dandge, M.S., Bhale, V.M. and Paslawar, A.N. 2014. Integrated weed management in maize. *In*: Biennial Conference of Indian Society of Weed Science on *"Emerging challenges in weed management"* Jabalpur, February, 15-17: pp. 81.

Deshmukh, L.S., Jadhav, A.S. and Raskar, S.K. 2009. Effect of nutrient and weed management on weed growth and productivity of *kharif* maize under rainfed conditions. *Karnataka Journal of Agricultural Sciences* **22**: 889-891.

Dilshad, M.D., Lone, M.I., Jilani, G., Azim Malik, M., Yousaf, M., Khalid, R. and Shamin, F., 2010. Integrated nutrient management (IPNM) on maize under rainfed condition. *Pakistan Journal of Nutrition* **9**: 896-901.

Dobariya, V.K., Mathukia, R.K., Gohil, B.S. and Chhodavadia, S.K. 2014. Integrated weed management in sweet corn. *Indian Journal of Weed Science* **46**: 195-196.

Donald, C.M. and Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy* **28**: 361-405.

Douglas, L.A. and Bremner, J.M. 1970. Extraction and colorimetric determination of urea in soils. *Soil Science Society of America Proceeding* **34**: 859-862.

Duary, B., Sharma, P. and Teja, K.C. 2015. Effect of tanx-mix application of tembotrione and atrazine on weed growth and productivity of maize. *In*: 25th Asian-Pacific Weed Science Society Conference on *"Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during 13-16 October: pp.258.

Duncan, W.G. 1971. Leaf angle, leaf area and canopy photosynthesis. *Crop Science* **11**: 314-316.

Duraisami, V.P., Chitdeshwari, T., Subramanian, K.S. and Rajeswari R. 2007. Effect of micronutrients and sulphur on yield and nutrient uptake by maize in an alfisol. *Madras Agricultural Journal* **94**: 283-288.

Dwivedi, S.K., Singh, R.S. and Dwivedi, K.N. 2002. Effect of sulphur and zinc nutrition on yield and quality of maize in typic ustocrept soil of Kanpur. *Journal of the Indian Society of Soil Science* **50**: 70-74.

Dwivedi, S.K. and Shrivastava, G.K. 2011. Planting geometry and weed management for maize (*Zea mays*)-blackgram (*Vigna mungo*) intercropping system under rainfed *vertisols. Indian Journal of Agronomy* **56**(3): 202-208.

Dwivedi, S.K., Shrivastava, G.K., Singh, A.P. and Kolhe, S.S. 2011. Weed population, nitrogen removal by weeds and crop yield under maize+blackgram intercropping system in Chhattisgarh plains. *Indian Journal of Weed Science* **43**(3&4): 203-210.

Dwivedi, S.K., Shrivastava, G.K., Singh, A.P. and Lakpale, R. 2012. Weed and crop productivity of maize+blackgram intercropping system in Chhattisgarh plains. *Indian Journal of Weed Science* **44**(1): 26-29.

El-Metwally, I.M., Abd El-Salam, M.S., Tagour, R.M.H. and Abouziena, H.F. 2012. Efficiency of plant population and residual herbicides rate on maize productivity and associated weeds. *Journal of Applied Sciences Research* **8**: 2342-2349.

FAO (Food and Agricultural Organization) 2003. Food and Nutrition Paper 77. Methods of analysis and conversion factors. http://www.fao.org/docrep/006. Retrieved on 14 April, 2017.

Fazil, S., Nasir, Ud Din, Azim, A. and Shah, Z. 2007. Response of maize crop to various herbicides. *Pakistan Journal of Weed Science Research* **13**: 9-15.

Gantoli, G., Ayala, V.R. and Gerhards, R. 2013. Determination of the critical period for weed control in corn. *Weed Technology* **27**: 63-71.

Gatzweiler, E., Krahmer, H., Hacker, E., Hills, M., Trabold, K. and Bonfig-Picard, G. 2012. Weed spectrum and selectivity of tembotrione under varying environmental conditions. *25th German Conference on Weed Biology and Weed Control, Germany.* 13-15 March. pp: 385-391.

Ghassam, A., Alizadeh, H. and Bihamta, M. 2010. Efficacy of herbicides on yield and yield component in corn (*Zea mays*) in single and double row planting pattern. In: Proceedings of 3rd Iranian Weed Science Congress, Vol. 2: Key papers, weed management and herbicides, Babolsar, Iran, 17-18 February 2010 pp. 351-353.

Gomma, M.R., Allam, S.A.H. and El-Gedwy, El. M.M. 2011. Determination of the critical period of weed control in maize grown under different plant densities. *Journal of Plant Production* **2**: 1861-1878.

Gomez, K.A. and Gomez. A.A.1984. Statistical Procedures for Agricultural Research (2nd ed.). John Willey and Sons. Singapore.

Gopal, R., Jat, R.K., Malik, R.K., Kumar, V., Alam, M.M., Jat, M.L., Mazid, M.A., Saharawat, Y.S., McDonald, A and Gupta, R. 2010. Direct dry seeded rice production technology and weed management in rice based systems. NAIP, ICAR, CIMMYT and CSISA, NAAS Complex, New Delhi. pp.16.

Gopinath, K.A. and Kundu, S. 2008. Effect of dose and time of atrazine application on weeds in maize (*Zea mays*) under mid-hill conditions of North Western Himalayas. *Indian Journal of Agricultural Sciences* **48**: 254-257.

Gosavi, S.P., Chavan, S.A. and Bhagat, S.B. 2009. Effect of mulches, fertilizer and levels of FYM on yield attributes and yield of *rabi* sweet corn *(Zea mays saccharata). Journal of Soils and Crops* **19**: 84-87.

Govt. of India 2016. Directorate of economics and statistics, Department of Agriculture cooperation and farmers welfare, Ministry of Agriculture and farmers welfare, Government of India.

Govt. of Rajasthan 2016. Agricultural Statistics at a Glance, Directorate of Agriculture, Rajasthan, Jaipur.

Gul, S. and Khanday, B.A. 2015. Influence of fertility levels and weed management practices on yield and yield attributes of rainfed maize. *Scientific Research and Essays* **10**: 659-663.

Gul, S., Khan, M.H., Khanday, B.A. and Nabi, S. 2015. Effect of sowing methods and NPK levels on growth and yield of rainfed maize (*Zea mays* L.). Hindawi Publishing Corporation Scientifica **1**: 1-6.

Gul, S., Khanday, B.A. and Khan, M.H. 2016. Effect of fertility levels and herbicide mixtures on yield and yield attributes of rainfed maize under temperate conditions of Kashmir. *Applied Biological Research* **18**(2): 185-191.

Gupta, O.P. 2012. Modern Weed Management. Agrobios India, Jodhpur, pp.253.

Hamayun, M. 2003. Effect of spacing and weed free periods on the productivity of maize (*Zea mays* L.). *Pakistan Journal of Weed Science Research* **9**: 179-184.

Hawaldar, S. and Agasimani, C.A. 2012. Effect of herbicides on weed control and productivity of maize (*Zea mays* L.). *Karnataka Journal of Agricultural Sciences* **25**: 137-138.

Holford, I.C.R., Haigh, B.M. and Ferris, I.G. 2012. Atrazine persistence and phytotoxicity on wheat as affected by nitrogen and rotation induced changes in soil properties. *Australian Journal of Agricultural Research* 40: 1143-1153.

Idziak, R. and Woznica, Z. 2014. Impact of tembotrione and flulenacet plus isoxaflutole application timings, rates and adjuvant type on weeds and yield of maize. *Chilean Journal of Agricultural Research* **74**: 2.

IIMR. 2011. Integrated weed management in maize and its residual effect on wheat grown under maize – wheat cropping systems at Pantnagar. Annual Report of AICRP maize Agronomy (*rabi* 2010-11 and *kharif* 2011), Indian Institute of Maize Research, IARI, New Delhi, pp: 193.

IIMR. 2015. Weed management in maize system at Bajaura. *In*: Annual Progress Report of AICRP maize. Indian Institute of Maize Research, IARI, New Delhi, pp: A-151.

Jackson, M.L. 1973. Soil Chemical Analysis. Ed. 2. Prentice Hall Inc. Pvt. Ltd., New Delhi. pp. 134-82.

Jat, S.L., Parihar, C.M., Singh, A.K., Jat, M.L., Sinha, A.K., Mishra, B.N., Meena, H., Paradkar, V.K., Singh, C.S., Singh, D. and Singh, R.N. 2013. Integrated nutrient management in quality protein maize (*Zea mays* L.) planted in rotation with wheat (*Triticum aestivum* L.). *Indian Journal of Agricultural Sciences* **83**: 391-396.

Jena, N., Vani, K.P., Rao, P. and Sankar, A.S. 2013. Effect of nitrogen and phosphorus fertilizers on growth and yield of quality protein maize (QPM). *International Journal of Science and Research* **4**: 197-199.

Jonathon, R., Kohrt and Christy, L., Sprague. 2013. Weed height and the inclusion of atrazine influence control of multiple-resistant Palmer amaranth with HPPD inhibitors. Weed Technology **43**: 2.

Joseph, D., Bollman, M., Boerboom, Roger, L., Becker and Fritz 2008. Efficacy and tolerance to HPPD-inhibiting herbicides in sweet corn. *Weed Technology* **22**: 666-674.

Joshi, E. 2012. Studies on nutrient management in maize (*Zea mays* L.). M.Sc. (Ag.) Thesis, Department of Agronomy, Maharana Pratap University of Agriculture and Technology, Udaipur.

Joshi, E., Vyas, A.K., Dass, Anchal and Dhar, Shiva. 2016. Nutrient omission effects on yield, water productivity and profitability of maize (*Zea mays*). *Indian Journal of Agronomy* **61**(2): 204-209.

Kamble, T.C., Kakade, S.U., Nemade, S.U., Pawar, R.V. and Apotikar, V.A. 2005. An integrated weed management in hybrid maize. *Crop Research (Hisar)* **29**: 396-400.

Karki, T.B. and Kumar, A. 2004. Effects of organic and inorganic sources of nutrients on growth, yield and nutrient uptake by maize (*Zea mays* L.) *Agronomy Digest* **4**: 18-20.

Khajanji, N.S., Patel, R.J. and Gautam, R.C. 2006. Effect of tillage and weed control methods on weed dry weight, economics, energetic and yield of *kharif* maize. *Journal of Maharashtra Agricultural University* **31**: 19-21.

Korpff, M.J. 1993. Mechanism of competition for light. *In*: M.J. Korpff and H.H. Vanlar (edition). Modeling Crop Interaction. CAB, Internet & Manila, The Philippines.

Kour, P., Kumar, A., Sharma, B.C., Kour, R., Kumar, J. and Sharma, N. 2014. Effect of weed management on crop productivity of winter maize *(Zea mays)* + potato *(Solanum tuberosum)* intercropping system in Shiwalik foothills of Jammu and Kashmir. *Indian Journal of Agronomy* **59**(1): 65-69.

Kour, P., Kumar, A. Sharma, N., Kumar, J. and Mahajan, A. 2016. Increase in yield of winter maize+potato intercropping system by weed management. *Indian Journal of Weed Science* **48**(4): 387–389.

Krishna, K.B. 2012. Maize ecosystems – nutrient dynamics and productivity. Apple Academic Press Inc., Canada.

Kumar, A. 2008. Productivity, economics and nitrogen use efficiency of speciality corn (*Zea mays*) as influenced by planting density and nitrogen fertilization. *Indian Journal of Agronomy* **53**: 306-309.

Kumar, A. and Dhar, S. 2010. Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays*) and their residual effect on wheat (*Triticum aestivum*) under different fertility levels. *Indian Journal of Agricultural Sciences* **80**: 364-371.

Kumar, A. and Thakur, K.S. 2005. Influence of intercropping and weed control measures on weeds and productivity of rain fed maize (Zea *mays*). *Indian Journal of Weed Science* **37**: 65-67.

Kumar, A., Thakur, K.S. and Munujia, S. 2002. Effect of fertilizer levels on fertility on promising hybrid maize under rain fed condition of Himachal Pradesh. *Indian Journal of Agronomy* **47**: 526-530.

Kumar, S., Rana, S.S., Chander, N. and Angiras, N.N. 2012. Management of hardy weeds in maize under mid hill conditions of Himachal Pradesh. *In*: Extended Summaries Vol. 3: 3rd International Agronomy Congress: Agriculture Diversification, Climate Change Management and Livelihoods, Nov. 26-30, 2012, Indian Society of Agronomy, New Delhi. pp. 682-684.

Kumar, V. and Jha, P. 2015. Effective pre emergence and post emergence herbicide programs for kochia control. *Weed Technology* **29**: 24-34.

Kumar, V.S. and Pitchari, G.J. 2010. Effect of various sources of organic manures on yield and yield attributes of irrigated maize (*Zea mays* L.). *Asian Journal of Soil Science* 5: 399-401.

Kumari Geetha A., Sanjay, M.T., Prasad Ramachandra, T.V., Rekha, B. and Hatti, Veeresh 2015. Influence of new herbicide molecules on weed growth and yield of maize. *In*: 25th Asian-Pacific Weed Science Society Conference on *"Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during 13-16 October: pp.253.

Larbi, E., Ofosu-Anim, J., Norman, J.C., Anim-Okyere, S. and Danso, F. 2013. Growth and yield of maize (*Zea mays* L.) in response to herbicide application in the coastal savannah ecozone of Ghana. *Net Journal of Agricultural Science* **1**: 81-86.

Lindner, R.C. 1944. Rapid analytical methods for more common organic substances of plant and soil. *Plant Physiology* **19**: 76-84.

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421-428.

Li Yu., Eerd, L.L.V., OHalloran, I., Sikkema, P.H.,and Robinson, D.E. 2015. Response of four spring-seeded cover crops to residues of selected herbicides. *Canadian Journal of Plant Science* **95**(2): 303-313.

Lowry, O.H., Rosenbrough, N.J., Farr, A.L. and Ronald, R.J. 1951. Protein measurement with the folin phenol reagent. *Journal of Biological Chemistry* **193**: 265-75.

Malviya, A., Malviya, N., Singh, B. and Singh, A.K. 2012. Integrated weed management in maize *(Zea mays)* under rainfed conditions. *Indian Journal of Dryland Agricultural Research and Development* **27**(1): 70-73.

Malviya, A. and Singh, B. 2007. Weed dynamics, productivity and economics of maize (*zea mays*) as affected by integrated weed management under rainfed condition. *Indian Journal of Agronomy* **52**: 321-324.

Mandal, S., Mondal, S. and Nath, S. 2004. Effect of integrated weed management on yield components, yield and economics of baby corn (*Zea mays*). *Annals of Agricultural Research (New Series)* **25**: 242-244.

Manea, M., Sen, A., Kumar, A., Kumar, P., Singh, Y., Shrivastava, V.N. and Singh, R.K. 2015. Performance of baby corn (*Zea mays* L.) under different fertility and planning methods and its residual effect on sorghum. *Indian Journal of Agronomy* **60**: 45-51.

Mani, V.S., Gautam, K.C. and Chakraberty, T.K. 1968. Losses in crop yield in India due to weed growth. *PANS* **42**: 142-158.

Martin, M., Williams II, Boydston, R.A., Peachey, R.Ed. and Robinson, D. 2011. Significance of atrazine as a tanx mix partner with tembotrione. *Weed Technology* **25**: 299-302.

Meyyappan, M. and Kathiresan, R.M. 2005. Integrated weed management in maize + blackgram intercropping system. *Indian Journal of Weed Science* **37**(3&4): 209-211.

Mehta, Y.K., Shaktawat, M.S. and Singhi, S.M. 2005. Influence of sulphur, phosphorus and farmyard manure on yield attributes and yield of maize (*Zea mays*) in southern Rajasthan conditions. *Indian Journal of Agronomy* **50**: 203-205.

Milcic, B., Radin, D. and Terzic V. A. 2003. Inactivation - detoxication of simazine and atrazine in various soils. *Zemljiste i biljka.* **52**: 13-23.

Misra, B.N., Singh, B. and Rajput, A.L. 2001. Yield, quality and economics as influenced by winter maize *(Zea mays)* based intercropping system in eastern Uttar Pradesh. *Indian Journal of Agronomy* **46**: 425-431.

Nadiger, S., Babu, R. and Kumar, B.N.A. 2013. Bioefficacy of pre-emergence herbicides on weed management in maize. *Karnataka Journal of Agricultural Sciences* **26**(1): 17-19.

Naidu, V.S.G.R. and Murty, T.G.K. 2014. Weed interactions under climate change. *Indian Journal of Weed Science* **46**: 61-65.

Najafi, B. and Ghardiri, H. 2012. Weed control and grain yield response to nitrogen management and herbicides. *Journal of Biological and Environmental Sciences* **6**(16): 39-47.

Nosratti, I., Alizade, H.M. and Makmasoumi, T. 2007. Evaluation the efficacy of three sulfonylurea herbicides and their effects on maize (*Zea mays* L.) grain yield. *Journal of Biological Sciences* **7**: 1262-1265.

Oerke, Ec. and Dehne, Hw. 2004. Safeguarding production losses in major crops and the role of crop protection. *Crop Portection* **23**: 275-285.

Oliveiria Junior, R. S. de. 2001. Carryover of imazaquin and alachlor+atrazine to the successional canola crop. *Ciencia Rural* **31**: 219-224.

Olsen, S.R., Cole, S.W., Watenable, P.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with $NaHCO_3$ *USDA*, 931.

Om, H., Singh, S.P., Singh, J.K., Singh, R.N., Ansari, M.A., Meena, R.L. and Yadav, B. 2014. Productivity, nitrogen balance and economics of winter maize (*Zea mays* L.) as influenced by QPM cultivars and nitrogen levels. *Indian Journal of Agricultural Sciences* **84**: 306-308.

Owla, M.L., Nepalia, V., Chouhan, G.S. and Singh, D. 2015. Effect of fertility levels, nutrient sources and weed control on weed dynamics and yield of quality protein maize *(Zea mays)* and relative nitrogen and phosphorus uptake. *Indian Journal of Agronomy* **60**(2): 267-272.

Paltasingh, K.R., Goyari, P. and Mishra, R.K. 2012. Measuring weather impact on crop yield using aridity index: *Odisha Agricultural Economics Research Review* **25**: 205-216.

Pandey, A.K. and Prakash, V. 2002. Weed management in maize and soybean intercropping system. *Indian Journal of Weed Science* **34**: 1-2.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers. ICAR, New Delhi.

Paramasivan, M., Kumaresan, K.R., Malarvizhi, P., Mahimairaja, S. and Velayudham, K. 2011. Effect of different levels of NPK and Zn on yield and nutrient uptake by hybrid maize (COHM 5) in Pilamedu and Palaviduthi series of Tamil Nadu. *Madras Agricultural Journal* **98**(10-12): 334-338.

Paramasivan, M., Malarvizhi, P. and Thiyageswari, S. 2012. Balanced use of inorganic fertilizers on maize *(Zea mays)* yield, nutrient uptake and soil fertility in alfisols. *Karnataka Journal of Agricultural Sciences* **25**: 423-426.

Paramesh, V., Dhar, S., Vyas, A.K. and Dass, A. 2014. Studies on impact of phosphoenriched compost, chemical fertilizer and method of zinc application on yield, uptake and quality of maize (*Zea mays*). *Indian Journal of Agronomy* **59**(4): 613-618.

Paradkar, V.K., Tiwari, D.K. and Reddy, R.K. 2010. Response of baby corn to integrated nutrient management. In: *Extend Summaries,* XIX National symposium on Resource Management Approaches towards Livelihood Security, organized by Indian Society of Agronomy at University of Agricultural Sciences Bengaluru India., Dec 2-4, pp. 37.

Patel, V.J., Upadhyay, P.N., Patel, J.B. and Patel B.D. 2006 a. Evaluation of herbicide mixtures for weed control in maize *(Zea mays* L.) under middle Gujarat conditions. *The Indian Journal of Agricultural Sciences* **2**: 81-86.

Patel, V.J., Upadhyay, P.N., Zala, S.U. and Patel, B.D. 2006 b. Residual effect of herbicide applied as alone and in mixture to *kharif* maize on succeeding *rabi* oat and mustard. *Indian Journal of Weed Science* **38**: 258-262.

Patel, V.P., Upadhyay, P.N., Patel, J.B. and Meisuriya, M.T. 2006 c. Effect of herbicide mixture on weeds in *kharif* maize (*Zea mays* L.) under middle Gujarat conditions. *Indian Journal of Weed Science* **38**: 54-57.

Pathak, S.K., Singh, S.B., Jha, B.N. and Sharma, R.P. 2005. Effect of nutrient management on nutrient uptake and changes in soil fertility in maize–wheat cropping system. *Indian Journal of Agronomy* **50**: 269-273.

Pathak, S.K., Singh, S.B. and Singh, S.N. 2002. Effect of integrated nutrient management on growth, yield and economics in maize (*Zea mays*) - wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **47**: 325-332.

Peyvastegan, S. and Farahbakhsh, A. 2011. The residual effects of different doses of atrazine+alachlor and foramsulfuron on the growth and physiology of rapeseed (*Brassica napus L.*). *International Journal of Agricultural and Biosystems Engineering* **5**(2): 88-93.

Piper, C.S. 1950. Soil and Plant Analysis. Inter science Publisher. Inc. New York, USA.

Prasad, A., Singh, G. and Upadhyay, R.K. 2008. Integrated weed management in maize (*Zea mays* L.) and maize+blackgram. *Indian Journal of Weed Science* **40** (3&4): 191-192.

Prasad, R., Singh, S. and Sharma, S.N. 1998. Interrelationships of fertilizer use and other agricultural inputs for higher crop yields. *Fertilizer News* **43**: 35-54.

Prasanna, B.M., Vasal, S.K., Kassahun, B. and Singh, N.V. 2001. Quality protein maize. *Current Science* **81**: 1308-1319.

Rana, S.S., Badiyala, D., Sharma, N., Kumar, R. and Pathania, P. 2017. Impact of tembotrione on weed growth, yield and economics of maize (*Zea mays* L.) under mid hill conditions of Himachal Pradesh. *Pesticide Research Journal* **29**(1): 27-34.

Rao, A.S., Ratnam, M. and Reddy, T.Y. 2009. Weed management in zero-till sown maize. *Indian Journal of Weed Science* **41**: 46-49.

Rao, V.S. 2000. Principles of Weed Science. Oxford and IBH Publishing Company. Private Limited, New Delhi.

Reddy, D.A. and Tyagi, S.K. 2005. Integrated weed management in maize- groundnut sequential cropping system. *Agricultural Reviews* **26**: 235-248.

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

Richard, H., Shimabukuro and Swanson, R. 1969. Atrazine metabolism, selectivity and mode of action. Metabolism and Radiation Research Laboratory, U.S. Department of Agriculture, Fargo, N.D. **17** (2): 19.

Richards, L.A. 1968. Diagnosis and improvement of saline and alkaline soils. Hand Book No.60, Oxford and IBH Publishing Co., New Delhi.

Saeed, M., Khaliq, A., Cheema, Z.A. and Ranjha, M. 2010. Effect of nitrogen levels and weed crop competition durations on yield and yield components of maize. *Journal of Agricultural Research* **48**: 471-481.

Saha, M. and Mondal, S.S. 2006. Influence of integrated nutrient supply on growth, productivity and quality of baby corn *(Zea mays)* in Indo-gangatic plains. *Indian Journal of Agronomy* **51**: 202-205.

Sahoo, S.C. and Mahapatra, P.K. 2005. Response of sweet corn (*Zea mays*) to fertility levels under on farm situation. *Indian Journal of Agricultural Sciences* **75**: 603-604.

Sahoo, S.C. and Mahapatra, P.K. 2007. Yield and economics of sweet corn (*Zea mays* L.) as affected by plant population and fertility levels. *Indian Journal of Agronomy* **52**: 239-242.

Saini, J.P. and Angiras, N.N. 1998. Efficacy of herbicides alone and in mixture to control weeds in maize under mid-hill conditions of Himachal Pradesh. *Indian Journal of Weed Science* **30**: 65–68.

Sanodiya, P., Jha, A.K., Shrivastava, A. and Chouhan, A. 2014. Effect of integrated weed management on seed yield of fodder maize. *In*: Biennial Conference of Indian Society of Weed Science on *"Emerging challenges in weed management"* Jabalpur, February, 15-17: pp.144.

Schlenker, W. 2006. Inter-annual weather variation and crop yields. http://nber15.nber.org/c/2006/si2006/ee/schlenker.pdf.

Scoot, M.P., Bhatnagar, S. and Betran, J. 2004. Tryptophane and methionine levels in quality protein maize breeding germplasm. *Maydica* **4**: 303-311.

Shankar, K.A., Yogesh, Prashanth, L.N.S.M., Channabasavanna, A.S. and Channagoudar, R.F. 2016. Effect of weed management practices on weed growth and yield of maize. *International Journal of Science, Environment and Technology* **4**: 1540-1545.

Sharana, F.A., El-Shahawy, A. and El-Rakich. 2005. Effect of some novel herbicides on the controlling of weeds associated with maize plants. *Journal of Agronomy* **4**(2): 88-95.

Sharma, C.K. and Gautam, R.C. 2010. Weed growth, yield and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed control methods. *Indian Journal of Agronomy* **55**: 290-303.

Sharma, R. and Pankaj. 2013. Direct and residual effect of different herbicides applied in maize *(Zea mays)* on weed dynamics and productivity of maize and succeeding wheat *(Triticum aestivum). Indian Journal of Agricultural Sciences* **83**: 77-82.

Shrinivas, C.S., Channabasavanna, A.S., Desai, B.K. and Rao, S. 2015. Evaluation of sequential application of herbicides on weed control and yield of maize. *In*: 25th Asian-Pacific Weed Science Society Conference on *"Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during 13-16 October: pp.274.

Silva, P.S.L., Silva, E.S. and Mesquita, S.S.X. 2004. Weed control and green ear yield in maize. *Planta daninha* **22** (1).

Singh, A. K., Parihar, C. M., Jat, S. L., Singh, B. and Sharma, S. 2015. Effect on weed dynamics, productivity and economics of the maize-wheat (*Triticum aestivum*) cropping system in Indo-gangetic plains. *Indian Journal of Agricultural Sciences* **85**: 87–92.

Singh, D. 2010. Impact of scheduling nitrogen on productivity of single cross maize (*Zea mays* L.) hybrids. *Indian Journal of Agricultural Science* **80**: 649-651.

Singh, D., Pyare L., Pandey, P.C., Bistha, P.S. and Singh, S.K. 2012 a. Integrated weed management in transplanted rice (*Oriza sativa* L.). *Environment and Ecology* **30**: 1146-1149.

Singh, D. and Yadav, L.R. 2007. Effect of organic manures, chemical fertilizers and phosphorus sources on quality protein maize (*Zea mays*). *Agronomy Digest* **7**: 15-17.

Singh, G., Marwaha, T.S. and Kumar, D. 2009 a. Effect of resource conserving techniques on soil microbiological parameters under long term maize (*Zea mays*) – wheat (*Triticum aestivum*) crop rotation. *Indian Journal of Agricultural Sciences* **79**: 94-100.

Singh, M.K., Singh, R.N., Singh, S.P., Yadav, M.K. and Singh, V.K. 2010. Integrated nutrient management for higher yield, quality, profitability of baby corn (*Zea mays*). *Indian Journal of Agronomy* **55**: 100-104.

Singh, M., Prabhkumar, S., Sairam, C.V. and Kumar, A. 2009 b. Evaluation of different weed management practices in rainfed maize on farmer's field. *Pakistan Journal of Weed Science Research* **15**: 183-189.

Singh, M., Singh, P. and Nepalia, V. 2005. Integrated weed management studies in maize based intercropping system. *Indian Journal of Weed Science* **37**(3&4): 205-208.

Singh, P., Singh, P. and Dawson, J. 2007. Correlation and regression studies of winter maize and weed interactions. *Indian Journal of Weed Science* **39**: 21-23.

Singh V.P., Guru, S.K., Kumar, A., Banga, A. and Tripathi, N. 2012 b. Bioefficacy of tembotrione against mixed weed complex in maize. *Indian Journal of Weed Science* **44**(1): 1-5.

Sinha, S.P. Prasad, S.M. and Singh, S.J. 2005. Nutrient utilization by winter maize (*Zea mays*) and weeds as influenced by integrated weed management. *Indian Journal of Agronomy* **50**: 303-304.

Smith, A.M. 2010. Effects of landscape position, rainfall, and tillage on residual herbicides. *Weed Technology* **24**(3): 361-368.

Sofi, P.A., Wani, S.A., Rathore, A.G. and Wani, S.H. 2009. Quality protein maize (QPM): Genetic manipulation for the nutritional fortification of maize. *Journal of Plant Breeding and Crop Science* **1**: 244-253.

Sonawane, R.K., Dandge, M.S., Kamble, A.S. and Shingrup, P.V. 2014. Effect of herbicides on nutrient uptake by weeds, crops and yields of *kharif* maize. *In*: Biennial Conference of Indian Society of Weed Science on *"Emerging challenges in weed management"* Jabalpur, February, 15-17: pp.95.

Srikanth, M., Amanullah, M.M., Muthukrishnan, P. and Subramanian, K.S. 2009. Growth and yield of hybrid maize (*Zea mays* L.) as influenced by plant density and fertility levels. *Indian Journal of Agricultural Sciences* **5**: 299-302.

Srinivasrao, C., Masord Ali, Venkatesjurarulu, T.R., Rupa, T.R., Singh, K.K., Kunante Kundu and Prasad, J.V. 2010. Direct and residual effects of integrated sulphur fertilization in maize (*Zea mays*) – chickpea (*Cicer arietinum)* supplying system on Typic ushocrept. *Indian Journal of Agronomy* **53**: 259-263.

Stanzen, L., Kumar, A., Sharma, B.C., Puniya, R. and Sharma, A. 2016. Weed dynamics and productivity under different tillage and weed-management practices in maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping sequence. *Indian Journal of Agronomy* **61**: 449-454.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Current Science* **27**: 259-260.

Subedi, K.D. and Ma, B.L. 2009. Assessment of some major yield limiting factors of maize production in a humid temperate environment. *Field Crops Research* **110**: 21-26.

Sunitha, N., Maheshwara, R. and Sadhineni, M. 2010. Effect of cultural manipulation and weed management practices on weed dynamics and performance of sweet corn (*Zea mays* L.). *Indian Journal of Weed Science* **42**: 184-188.

Sutalia, R. and Singh, R.N. 2005. Effect of planting time, fertility levels and phosphate solublizing bacteria on growth, yield and yield attributes of winter maize under rice-maize cropping system. *Indian Journal of Agronomy* **50**: 173-175.

Swetha, K., Madhavi, M., Pratibha, G. and Ramprakash, T. 2015. Weed management with new generation herbicides in maize. *In*: 25th Asian-Pacific Weed Science Society Conference on *"Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during 13-16 October: pp.255.

Tabatabai, M.A. and Bremner, J.M. 1969. Arylsulfatase activity in soils. *Soil Science Society of America Proceeding* **34**: 225-229.

Tabatabai, M.A. and Bremner, J.M. 1970. A simple turbidemetric method of determination of total sulphur in plant material. *Agronomy Journal* **62**: 805-806.

Tahir, M., Shabbir, G., Nadeem, M.A., Waseem, M., Javid, H.M.R. and Rehman, H. 2011. The effect of intensity of tillage and herbicide application on spring planted maize (*Zea mays* L.) and its weeds. *Pakistan Journal of Life and Social Sciences* **9**(2): 109-115.

Tak, R.C. 2000. Effect of zinc fertilization at different levels of nitrogen and phosphorous in conjunction with FYM on nutrient availability and yield of maize in Alfisol. Ph. D. Thesis, Department of Agricultural Chemistry and Soil Science. Maharana Pratap University of Agriculture and Technology, Udaipur.

Takim, F.O. 2012. Weed competition in maize (*Zea mays* L.) as a function of the timing of hand hoeing weed control in the southern Guinea Savanna zone of Nigeria. *Acta Agronomica Hungarica* **60**: 257-264.

Tetarwal, J. P., Ram B. and Meena, D. S. 2011. Effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in rainfed maize (*Zea mays*). *Indian Journal of Agronomy* **56**: 373-376.

Thakur, D.R. and Sharma, V. 1996. Integrated weed management in rainfed maize. *Indian Journal of Weed Science* **28**: 207–208.

Tollenaar, M., Nissanka, S.P., Agauilera, A., Weise, S.F. and Swanton, C.J. 1994. Effect of weed interference and soil nitrogen on four maize hybrids. *Agronomy Journal* **86**: 597-601.

Totawat, K.L., Somani, L.L., Singh, R. and Singh, G. 2001. Integrated nitrogen management in maize-wheat cropping sequence on typic Haplustalfs of western India. *Annals of Arid Zone* **40**: 439-444.

Umesha, C., Sridhara, S. and Aswini 2015. Effect of pre and post emergent herbicides on water use efficiency, nitrogen use efficiency, phosphorus use efficiency, potassium use efficiency and its residual effect on subsequent greengram crop. *Trends in Biosciences* **8**(10): 2475-2478.

Verma, A., Nepalia, V. and Kanthalia, P.C. 2006. Effect of nutrient supply on growth, yield and nutrient uptake by maize (*Zea mays*) - wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **51**: 3-6.

Verma, S., Verma, D.K., Giri, S.P., Singh, K., Singh, R.B. and Pandey, A. 2015. Response of chemical weed management in maize and cowpea intercropping system grown for quality fodder in eastern Uttar Pradesh. *International Journal of Forestry and Crop Improvement* **6**(2): 105-109.

Verma, V.K., Paradkar, V.K., Reddy, R.K., Tiwari, D.K. and Rout, R.L. 2012. Integrated nutrient management for improving yield of quality protein maize. *In*: Extended Summaries Vol. 3: 3rd International Agronomy Congress: Agriculture Diversification, Climate Change Management and Livelihoods, Nov. 26-30, 2012, Indian Society of Agronomy, New Delhi. pp. 1243-44.

Verma, V.K., Tewari, A.N. and Dhemri, S. 2009. Effect of atrazine on weed management in winter maize-greengram cropping system in central plain zone of Uttar Pradesh. *Journal of Agricultural Science* **41**(1&2): 41-44.

Villasana, R., Rodriguez, A.B., Perez, D., Fernandez, J., Sanchez, P. and Uranga, H. 2004. Determination of critical period of competition between weeds and corn. III Congress, Cuba.

Vyn, J.D., Swanton, C.J., Weaver, S.E. and Sikemma, P.H. 2006. Control of *Amaranthus tuberculatus var. rudis* (common water hemp) with pre and post emergence herbicides in *Zea mays* L. (maize). *Crop Protection* **25**: 1051-1056.

Waddington, M.A. and Young, B.G. 2006. Interactions of herbicides and adjuvants with AE on postemergence grass control. *Weed Science* **61**: 108-115.

Walia, U.S., Brar, L.S. and Singh, B. 2005. Recommendation for weed control in field crops. *Research Bulletin*. Department of Agronomy, Agrometeorology and Forestry, PAU, Ludhiana, pp.5.

Walia, U.S., Singh, S. and Singh, B. 2007. Integrated control of hardy weeds in maize (*Zea mays* L.). *Indian Journal of Weed Science* **39**: 17-20.

Walkley, A. and Black, I.A. 1947. Rapid titration method for organic carbon of soil. *Soil Science* **37**: 29-32.

Yazdanpak, A., Amiri, A., Faghihi, K. and Karimian, N.A. 2014. The residual effect of herbicides on the germination and early growth of shiraz wheat cultivar in the development of healthy agricultural crops. *American-Eurasian Journal of Agricultural & Environmental Sciences* **14**(2): 161-164.

Zaremohazabieh, S. and Ghardiri H. 2011. Effect of rimsulfuron, foramsulfuron and conventional herbicides on weed control and maize yield at three planting dates. *Journal of Biological and Environmental Sciences* **5**(14): 47-56.

Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)

Versha Gupta* **Dr. Arvind Verma****

Research Scholar **Major Advisor**

ABSTRACT

A field experiment entitled **"Effect of Weed Management and Nutrient Application on Productivity of Quality Protein Maize (*Zea mays* L.) and their Residual Effect on Succeeding Wheat (*Triticum aestivum* L.)"** was conducted during the year 2015-16 and 2016-17 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur. The experiment consisted of nine weed management treatments *viz*., weedy check, hand weeding at 15 DAS and 35 DAS, tembotrione 0.125 kg ha^{-1} at 20 DAS, alachlor 2.0 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, tembotrione 0.125 kg ha^{-1} at 20 DAS *fb* hand weeding at 35 DAS, alachlor 2.0 kg ha^{-1} + atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, alachlor 2.0 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS and atrazine 0.5 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS with three nutrient management treatments *viz*., NPK, NPK+Zn and NPKS+Zn, thereby making 27 treatment combinations. The experiment was laid out in split plot design, assigning different weed management practices to main plots and nutrient applications to sub plots. The treatments were replicated thrice. Maize cv. Pratap QPM-1 and wheat cv. Raj-4079 were used as test crops and crops were raised as per package of practices recommended for agro climatic zone IVa of Rajasthan.

All the weed management treatments caused significant reduction in density and dry matter of all category of weeds at all growth stages and nutrient removal by them at harvest. Maximum reduction of weed density, dry matter and nutrient uptake by weeds as well as highest weed control efficiency were recorded in crop subjected to atrazine *fb* tembotrione and its response was closely followed by alachlor *fb* tembotrione and two hand weedings at 15 and 35 DAS.

Plant height at 30 DAS and at harvest increased significantly through all weed management treatments over weedy check. The plant height at harvest was significantly

* **Research Scholar, Department of Agronomy, RCA, MPUAT, Udaipur.**

** **Professor, Department of Agronomy, RCA, MPUAT, Udaipur.**

higher with atrazine *fb* tembotrione but it was statistically at par with application of alachlor *fb* tembotrione and two hand weedings. The dry matter accumulation by QPM at 30 DAS and 60 DAS significantly increased by atrazine *fb* tembotrione and it was closely followed by alachlor *fb* tembotrione and two hand weedings, while dry matter at harvest significantly higher with alachlor *fb* tembotrione and was at par with atrazine *fb* tembotrione, two hand weedings and alachlor+atrazine *fb* hand weeding.

Among all the weed management treatments atrazine *fb* tembotrione resulted in maximum number of grains cob^{-1} (367.91), weight of grains (82.79 g), test weight (212.03 g) and shelling per cent (76.58 %), while days to 50% silking and number of cobs plant^{-1} were found unaffected with different weed management treatments. Atrazine *fb* tembotrione produced significantly higher pooled values of grain (4516 kg ha^{-1}), stover (7459 kg ha^{-1}) and biological (11976 kg ha^{-1}) yields compared to other treatments. Atrazine *fb* tembotrione, alachlor *fb* tembotrione and two hand weedings resulted in 71.8, 71.1 and 71.2 per cent increase in pooled grain yield, respectively over weedy check (2628 kg ha^{-1}).

Various weed management treatments significantly increased N, P, K and S content of QPM in grain and stover (except K) over weedy check. Further, significantly higher N, P, K and S uptake by crop was observed compared to weedy check under various weed management treatments. Two hand weedings recorded maximum protein content in grain (12.04 %) and chlorophlyll content at 30 DAS (1.883 mg g^{-1}) but at 60 DAS chlorophlyll content was maximum with atrazine *fb* tembotrione (1.913 mg g^{-1}).

Nutrient management had no significant effect on weed density while weed dry matter was significantly affected by different nutrients in either of the years. Further, nutrient management had no significant effect on N, P and K uptake (except S uptake) by weeds at harvest. Maximum plant height and dry matter accumulation at 30, 60 DAS and at harvest were recorded under the application of NPKS+Zn.

Nutrient application of S and Zn with NPK to QPM recorded significant improvement in yield attributes *viz.,* number of grains cob^{-1}, weight of grain, test weight and shelling per cent while days to 50% silking and number of cobs plant^{-1} were found unaffected with different nutrient management treatments. Application of NPKS+Zn increased grain, stover and biological yields of QPM by 7.52, 7.27 and 7.36 per cent, respectively over NPK. Maximum N, P, K and S content in grain and stover (except K) was recorded with the application of NPKS+Zn. Similarly, application of NPKS+Zn registered the highest total N, P, K and S uptake, protein and chlorophyll content at 30 and 60 DAS by QPM.

Soil pH, EC and organic carbon at harvest of QPM remained unaffected with various weed and nutrient management treatments. Further, different weed and nutrient management treatments failed to cause any significant effect on available nitrogen, phosphorus, potassium and sulphur nutrients in soil at harvest as well as soil enzyme dehydrogenase, phosphatase and urease activity at harvest of QPM.

Amongst weed management treatments the highest net return of ₹ 70254 ha^{-1} was obtained through atrazine *fb* tembotrione that correspondingly showed the highest B:C ratio of 2.74. Net return of ₹ 64862 ha^{-1} was realized through NPKS+Zn while maximum B:C ratio (2.48) was recorded with NPK among different nutrient management treatments.

Under residual response on succeeding wheat, no significant effect of weed and nutrient management treatments applied to QPM was observed on weed density and dry matter in wheat as well as plant height, dry matter accumulation, yield parameters (*viz.*, number of tillers $metre^{-1}$ row length, spike length, number of grains $spike^{-1}$ and 1000-grain weight), grain, straw, biological yield and harvest index of wheat during both the years of experimentation.

गुणवत्ता प्रोटीन मक्का (*जिया मेज* एल.) की उत्पादकता पर खरपतवार प्रबन्धन एवं पोषक तत्व अनुप्रयोग का प्रभाव तथा अनुगामी गेहूँ (*ट्रिटिकम एस्टीवम* एल.) पर उनका अवशिष्टकारी प्रभाव

वर्षा गुप्ता*
शोधकर्ता

डॉ. अरविन्द वर्मा**
मुख्य सलाहकार

अनुक्षेपण

राजस्थान कृषि महाविद्यालय के प्रशिक्षणात्मक प्रक्षेत्र (सस्य विज्ञान) पर वर्ष 2015-16 एवं 2016-17 में ''गुणवत्ता प्रोटीन मक्का (*जिया मेज* एल.) की उत्पादकता पर खरपतवार प्रबन्धन एवं पोषक तत्व अनुप्रयोग का प्रभाव तथा अनुगामी गेहूँ (*ट्रिटिकम एस्टीवम* एल.) पर उनका अवशिष्टकारी प्रभाव'' नामक शीर्षक पर क्षेत्र परीक्षण आयोजित किये गये। परीक्षण में नौ उपचार जिनमें खरपतवार युक्त, बुवाई के 15 एवं 35 दिन पश्चात् हाथ से निराई, बुवाई के 20 दिन बाद टेम्बोट्रिओन 0.125 किग्रा. प्रति हैक्टेयर, एलाक्लोर 2.0 किग्रा. प्रति हैक्टेयर अंकुरण पूर्व के साथ बुवाई के 35 दिन बाद एक निराई, एट्राजिन 0.5 किग्रा. प्रति हैक्टेयर अंकुरण पूर्व के साथ बुवाई के 35 दिन बाद एक निराई, बुवाई के 20 दिन बाद टेम्बोट्रिओन 0.125 किग्रा. प्रति हैक्टेयर के साथ बुवाई के 35 दिन बाद एक निराई, एलाक्लोर 2.0 किग्रा. प्रति हैक्टेयर + एट्राजिन 0.5 किग्रा. प्रति हैक्टेयर अंकुरण पूर्व के साथ बुवाई के 35 दिन बाद एक निराई, एलाक्लोर 2.0 किग्रा. प्रति हैक्टेयर अंकुरण पूर्व के साथ बुवाई के 20 दिन बाद टेम्बोट्रिओन 0.125 किग्रा. प्रति हैक्टेयर, एट्राजिन 0.5 किग्रा. प्रति हैक्टेयर अंकुरण पूर्व के साथ बुवाई के 20 दिन बाद टेम्बोट्रिओन 0.125 किग्रा. प्रति हैक्टेयर का क्रमबद्ध प्रयोग तथा तीन पोषक तत्व प्रबन्धन (एन.पी.के., एन.पी.के.+जिंक एवं एन.पी.के.एस.+जिंक) प्रयुक्त किये गये। इस प्रकार कुल 27 उपचार संयोजन बने। परीक्षण उपचारों को विभाजित खण्ड अभिकल्पना में, विभिन्न खरपतवार प्रबन्धन उपचारों को मुख्य खण्ड में और पोषक तत्व अनुप्रयोगों को उपखण्डों में तीन पुनरावृत्तियों के साथ प्रतिपादित किया गया। मक्का की किस्म प्रताप क्यू.पी.एम.–1 एवं गेहूँ की किस्म राज.–4079 को परीक्षण हेतु प्रयोग में लिया गया तथा फसल को राजस्थान के कृषि खण्ड IV अ की सस्य जलवायुवीय अनुशंसा अनुसार उगाया गया।

सभी खरपतवार नियंत्रण उपचारों से सभी वृद्धि अवस्थाओं पर सभी श्रेणी के खरपतवारों की सघनता शुष्क भार एवं कटाई के समय पोषक तत्वों की कमी होने में सार्थक रूप से कमी दर्ज की गई। खरपतवार सघनता, शुष्कभार, खरपतवारों द्वारा पोषक तत्वों के उद्ग्रहण में अधिकतम कमी के साथ सबसे अधिक खरपतवार नियंत्रण दक्षता एट्राजिन के साथ टेम्बोट्रिओन

* विद्यावाचस्पति शोध छात्रा, सस्य विज्ञान, राजस्थान कृषि महाविद्यालय, उदयपुर
** आचार्य, सस्य विज्ञान, राजस्थान कृषि महाविद्यालय, उदयपुर

के क्रमबद्ध प्रयोग करने से प्राप्त हुई एवं एलाक्लोर के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग तथा दो बार निराई का प्रभाव इसके उत्तरोत्तर रहा।

खरपतवार युक्त की अपेक्षा सभी खरपतवार नियत्रंण के उपचारों से मक्का के पौधों की 30 दिनों पर और कटाई की अवस्था पर ऊँचाई में सार्थक रूप से वृद्धि दर्ज की गई। कटाई की अवस्था पर पौधों की ऊँचाई में एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग करने से सार्थक वृद्धि हुई परन्तु सांख्यिक रूप से एलाक्लोर के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग तथा दो बार निराई के समतुल्य प्राप्त हुई। बुवाई के 30 और 60 दिनों बाद पौधों के शुष्क भार में खरपतवार युक्त की अपेक्षा एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग करने से सार्थक वृद्धि हुई, जबकि कटाई की अवस्था पर शुष्क भार एलाक्लोर के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग करने से यह खरपतवार युक्त की अपेक्षा सार्थक रूप से अधिक प्राप्त हुआ परन्तु यह सांख्यिक रूप से एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग तथा दो बार निराई के समतुल्य रहा।

सभी खरपतवार प्रबन्धन उपचारों में एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग के परिणामस्वरूप सबसे अधिक दानों की संख्या प्रति भूट्टा (367.91), दानों का वजन (82.79 ग्राम), परीक्षण वजन (212.03 ग्राम) एवं छीलन प्रतिशत (76.58 प्रतिशत) दर्ज किये गये जबकि मांजरे आने के दिन एवं भुट्टों की संख्या प्रति पौधा पर खरपतवार प्रबन्धन उपचारों का कोई सार्थक प्रभाव दर्ज नहीं हुआ। एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग ने दाने (4516 किग्रा. प्रति है.), भूसे (7459 किग्रा. है.) एवं जैविक उपज (11976 किग्रा. प्रति है.) के एकीकृत औसत मान में एलाक्लोर के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग, दो बार निराई, एलाक्लोर + एट्राजिन के साथ एक निराई तथा एट्राजिन के साथ एक निराई के अलावा सभी खरपतवार प्रबन्धन उपचारों की तुलना में सार्थक वृद्धि की। खरपतवार युक्त की तुलना में एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग, एलाक्लोर के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग एवं दो बार निराई के उपचार ने दाना उपज में क्रमशः 71.8, 71.1 एवं 71.2 प्रतिशत की वृद्धि दर्ज की, जो कि खरपतवार युक्त में 2628 किग्रा. प्रति हैक्टेयर थी।

विभिन्न खरपतवार प्रबन्धन उपचारों से गुणवत्ता प्रोटीन मक्का के दानों एवं भूसे (पोटाश के अलावा) में नत्रजन, फास्फोरस, पोटाश एवं गंधक के संचयन तथा नत्रजन, फास्फोरस, पोटाश एवं गंधक के उद्ग्रहण में खरपतवार युक्त की तुलना में सार्थक वृद्धि दर्ज की गई। हाथ द्वारा दो बार निराई से सर्वाधिक प्रोटीन संचयन (12.04 प्रतिशत) एवं 30 दिनों पर पर्णहरित संचयन (1.883 मिग्रा. प्रति ग्राम) दर्ज किया गया परन्तु 60 दिनों पर एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग से अधिकतम पर्णहरित संचयन (1.913 मिग्रा. प्रति ग्राम) प्राप्त किया गया।

दोनों वर्षों में पोषक तत्व प्रबन्धन का खरपतवारों की संख्या पर सार्थक रूप से कोई प्रभाव नहीं पड़ा जबकि उनके शुष्क भार में सार्थक रूप से वृद्धि दर्ज की गई। पोषक तत्व प्रबन्धन का खरपतवारों द्वारा नत्रजन, फास्फोरस एवं पोटाश (गंधक के अलावा) के उद्ग्रहण पर कोई सार्थक प्रभाव नहीं पड़ा।

एन.पी.के.एस.+जिंक के उपयोग से अधिकतम पादप ऊँचाई एवं शुष्क भार संचयन (बुवाई के 30, 60 दिन बाद एवं कटाई पर) दर्ज किया गया। एन.पी.के.एस.+जिंक के उपयोग से सार्थक रूप से अधिक दानों की संख्या प्रति भुट्टा, दानों का वजन, परीक्षण वजन एवं छीलन प्रतिशत प्राप्त हुए जबकि मांजरे आने के दिन एवं भुट्टों की संख्या प्रति पौधा अप्रभावित रहे। एन.पी.के. की तुलना में एन.पी.के.एस.+जिंक के उपयोग से दाना, भूसा एवं जैविक उपज क्रमशः 7.52, 7.27 एवं 7.36 प्रतिशत अधिक प्राप्त हुई।

एन.पी.के.एस.+जिंक के उपयोग से नत्रजन, फास्फोरस एवं गंधक का संचयन दानों एवं भूसे (पोटाश के अलावा) में सर्वाधिक दर्ज किया गया। गुणवत्ता प्रोटीन मक्का द्वारा नत्रजन, फास्फोरस, पोटाश एवं गंधक कुल उद्ग्रहण, प्रोटीन संचयन एवं पर्णहरित संचयन एन.पी.के.एस. .+जिंक के उपयोग में सर्वाधिक रहा।

खरपतवार प्रबन्धन के सभी उपचारों में अधिकतम शुद्ध लाभ (₹ 70254 प्रति है.) एवं लाभ–लाागत अनुपात (2.74) एट्राजिन के साथ टेम्बोट्रिओन के क्रमबद्ध प्रयोग से प्राप्त हुआ। एन.पी.के.एस.+जिंक के उपयोग से सार्थक रूप से अधिक शुद्ध लाभ (₹ 64862 प्रति है.) जबकि सर्वाधिक लाभ–लागत अनुपात (2.46) एन.पी.के. के उपयोग से प्राप्त हुआ।

दोनों वर्षों में अनुगामी गेहूँ पर, गुणवत्ता प्रोटीन मक्का में उपयोग किये गये खरपतवार प्रबन्धन एवं पोषक तत्व प्रबन्धन उपचारों का कोई सार्थक अवशिष्टकारी प्रभाव प्राप्त नहीं हुआ।

Appendix I: Analysis of variance for weed density at 30 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Echinochloa colona		*Cynodon dactylon*		*Cyperus rotundus*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	4.95	3.78	0.97	0.03	0.83	0.31
Weed mgt. (W)	8	5937.5*	4314.7*	46.0*	43.6*	37.4*	32.9*
Error (a)	16	6.4	4.0	0.6	0.3	1.2	0.5
Nutrient mgt. (F)	2	0.5	0.1	0.1	0.1	0.7	0.0
W x F	16	0.71	0.17	0.12	0.06	0.20	0.08
Error (b)	36	1.10	1.41	0.35	0.22	1.05	0.34

* Significant at 5 % level of significance

Appendix II: Analysis of variance for weed density at 30 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Dinebra retroflexa		*Brachiaria reptans*		*Amaranthus viridis*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.83	0.31	0.19	0.31	0.190	0.19
Weed mgt. (W)	8	598.1*	499.3*	72.5*	64.5*	95.1*	52.9*
Error (a)	16	1.2	0.5	1.2	0.5	1.211	1.2
Nutrient mgt. (F)	2	0.7	0.0	0.7	0.1	0.721	0.7
W x F	16	0.20	0.08	0.21	0.07	0.207	0.21
Error (b)	36	1.05	0.34	1.19	0.30	1.191	1.19

* Significant at 5 % level of significance

Appendix III: Analysis of variance for weed density at 30 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Digera arvensis		*Trianthema portulacastrum*		*Commelina benghalensis*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.01	0.99	3.35	3.24	1.76	1.49
Weed mgt. (W)	8	45.0*	41.2*	725.2*	629.1*	447.9*	240.2*
Error (a)	16	0.4	1.0	7.5	3.8	1.9	0.9
Nutrient mgt. (F)	2	0.1	0.0	0.3	0.3	0.4	0.0
W x F	16	0.40	0.10	0.74	0.24	0.23	0.10
Error (b)	36	0.33	0.31	5.79	2.49	1.23	0.84

* Significant at 5 % level of significance

Appendix IV: Analysis of variance for weed density at 30 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	15.57	6.95	9.12	7.64	18.39	12.12
Weed mgt. (W)	8	14845.8*	11518.1*	4091.8*	2868.2*	34471.9*	25844.5*
Error (a)	16	9.8	17.9	20.0	9.9	43.9	47.7
Nutrient mgt. (F)	2	8.1	1.5	5.2	1.3	25.9	4.4
W x F	16	3.17	0.67	1.73	0.37	7.08	1.30
Error (b)	36	9.87	4.68	9.00	2.89	28.82	8.74

* Significant at 5 % level of significance

Appendix V: Analysis of variance for weed density at 60 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Echinochloa colona		*Cynodon dactylon*		*Cyperus rotundus*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	13.68	3.39	12.25	0.43	2.59	0.57
Weed mgt. (W)	8	7628.9*	6358.1*	178.6*	111.1*	113.6*	92.3*
Error (a)	16	14.1	3.1	2.7	0.9	3.3	0.8
Nutrient mgt. (F)	2	0.2	0.1	0.5	0.1	0.0	0.0
W x F	16	0.13	0.11	0.10	0.16	0.10	0.21
Error (b)	36	0.30	2.46	2.39	0.88	2.85	0.68

* Significant at 5 % level of significance

Appendix VI: Analysis of variance for weed density at 60 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Dinebra retroflexa		*Brachiaria reptans*		*Amaranthus viridis*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.80	1.92	0.60	0.60	0.45	0.58
Weed mgt. (W)	8	998.2*	821.6*	126.2*	200.4*	189.6*	141.5*
Error (a)	16	3.4	1.1	1.3	1.3	1.6	1.2
Nutrient mgt. (F)	2	0.2	0.1	0.0	0.0	0.1	0.0
W x F	16	0.08	0.16	0.21	0.21	0.08	0.10
Error (b)	36	3.35	1.11	0.73	0.73	1.26	0.19

* Significant at 5 % level of significance

Appendix VII: Analysis of variance for weed density at 60 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Digera arvensis		*Trianthema portulacastrum*		*Commelina benghalensis*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	3.76	0.11	2.04	0.09	8.56	2.81
Weed mgt. (W)	8	219.0*	171.1*	1097.1*	756.1*	690.3*	362.3*
Error (a)	16	4.1	1.3	4.4	2.8	3.6	1.2
Nutrient mgt. (F)	2	0.1	0.1	0.2	0.0	0.0	0.0
W x F	16	0.16	0.08	0.21	0.14	0.15	0.16
Error (b)	36	3.90	1.25	0.85	2.00	3.57	0.81

* Significant at 5 % level of significance

Appendix VIII: Analysis of variance for weed density at 60 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	100.36	6.40	28.68	4.11	223.63	20.63
Weed mgt. (W)	8	23648.5*	20220.1*	7691.9*	5071.0*	58306.3*	45500.1*
Error (a)	16	62.4	19.1	34.2	14.1	173.1	56.8
Nutrient mgt. (F)	2	2.3	0.5	0.2	0.0	1.5	0.7
W x F	16	1.14	1.09	1.02	0.37	3.62	1.78
Error (b)	36	10.20	7.56	8.19	5.23	24.22	16.08

* Significant at 5 % level of significance

Appendix IX: Analysis of variance for weed dry matter at 30 DAS

Source of variance	d. f.	MSS					
		Weed dry matter (g m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.28	1.39	0.28	1.39	1.13	5.56
Weed mgt. (W)	8	1328.0*	1152.0*	1318.0*	1056.4*	5291.7*	4414.1*
Error (a)	16	1.8	1.0	1.8	1.0	7.1	4.0
Nutrient mgt. (F)	2	0.2	0.0	0.2	0.0	0.6	0.1
W x F	16	0.11	0.02	0.11	0.02	0.45	0.08
Error (b)	36	1.64	0.79	1.64	0.79	6.55	3.17

* Significant at 5 % level of significance

Appendix X: Analysis of variance for weed dry matter at 60 DAS

Source of variance	d. f.	MSS					
		Weed dry matter (g m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	4.37	18.26	2.01	2.88	6.79	30.90
Weed mgt. (W)	8	12756.1*	10351.3*	9390.0*	8342.6*	43510.0*	37140.7*
Error (a)	16	5.5	21.2	1.6	1.9	7.3	24.2
Nutrient mgt. (F)	2	18.9*	12.8*	11.9*	13.1*	60.9*	51.8*
W x F	16	0.03	0.03	0.03	0.03	0.11	0.11
Error (b)	36	4.79	3.50	0.98	0.75	5.88	3.90

* Significant at 5 % level of significance

Appendix XI: Analysis of variance for weed dry matter at harvest

Source of variance	d. f.	MSS					
		Weed dry matter (g m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	8.03	5.52	4.60	4.70	8.82	8.07
Weed mgt. (W)	8	28412.1*	26607.0*	27149.5*	25508.1*	111093.4*	104194.9*
Error (a)	16	7.3	17.7	14.6	38.1	30.9	91.9
Nutrient mgt. (F)	2	11.8*	13.5*	20.138*	19.5*	62.4*	65.4*
W x F	16	0.29	0.23	0.59	0.35	1.45	1.06
Error (b)	36	3.51	3.69	4.30	4.45	7.72	9.64

* Significant at 5 % level of significance

Appendix XII: Analysis of variance for nutrient content in weeds at harvest

Source of variance	d. f.	MSS							
		Content (%)							
		N		P		K		S	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	0.00124	0.00050	0.00012	0.00006	0.00071	0.00311	0.000062	0.000085
Weed mgt. (W)	8	0.00002	0.00001	0.00026	0.00031	0.00027	0.00038	0.000112	0.000202
Error (a)	16	0.00241	0.00305	0.00016	0.00017	0.00452	0.00420	0.000109	0.000116
Nutrient mgt. (F)	2	0.00417	0.00069	0.00000	0.00000	0.00102	0.00027	0.003566*	0.003500*
W x F	16	0.00428	0.00069	0.00000	0.00000	0.00102	0.00034	0.000189	0.000178
Error (b)	36	0.00181	0.00143	0.00008	0.00009	0.00055	0.00318	0.000045	0.000091

* Significant at 5 % level of significance

Appendix XIII: Analysis of variance for nutrient uptake by weeds at harvest

Source of variance	d. f.	MSS							
		Nutrient uptake (kg ha^{-1})							
		N uptake		P uptake		K uptake		S uptake	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	3.133	0.65	0.357	0.1615	1.6907	4.82	0.06	0.255
Weed mgt. (W)	8	1925.158*	1841.8*	70.481*	66.9341*	3025.27*	2852.2*	35.3*	34.707*
Error (a)	16	3.584	4.9	0.345	0.2862	4.5621	8.2	0.1	0.333
Nutrient mgt. (F)	2	0.938	0.3	0.032	0.0414	0.5042	2.1	1.5*	0.566*
W x F	16	0.951	0.21	0.001	0.0010	0.0625	0.08	0.18	0.159
Error (b)	36	0.754	0.57	0.115	0.0443	0.3217	1.00	0.01	0.094

* Significant at 5 % level of significance

Appendix XIV: Analysis of variance for plant population and plant height of QPM

Source of variance	d. f.	MSS							
		Plant population (m^{-2})				Plant height (cm)			
		30 DAS		At harvest		30 DAS		At harvest	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	1.411	4.241	18.271	11.173	33.73	6.28	53.50	38.31
Weed mgt. (W)	8	1.021	2.943	5.259	3.849	338.7*	475.5*	2877.2*	2658.6*
Error (a)	16	5.143	3.222	31.200	16.730	23.5	5.9	240.0	231.7
Nutrient mgt. (F)	2	0.838	3.160	2.032	0.688	82.1*	61.4*	280.5*	251.7*
W x F	16	1.607	1.225	0.827	0.978	170.65	2.47	24.59	24.03
Error (b)	36	3.446	2.786	4.001	9.303	12.43	8.50	84.15	77.14

* Significant at 5 % level of significance

Appendix XV: Analysis of variance for dry matter of QPM

Source of variance	d. f.	MSS					
		Dry matter accumulation (g plant^{-1})					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	9.937	6.78	9.69	17.63	454.78	39.33
Weed mgt. (W)	8	215.979*	260.4*	319.3*	310.1*	1350.8*	1331.1*
Error (a)	16	2.864	2.4	46.4	20.3	362.3	132.6
Nutrient mgt. (F)	2	14.029*	21.9*	98.4*	41.6*	1817.1*	294.5*
W x F	16	2.429	0.13	7.14	10.24	996.33	1.98
Error (b)	36	2.100	1.72	14.66	9.67	322.99	83.75

* Significant at 5 % level of significance

Appendix XVI: Analysis of variance for crop growth rate (CGR) and relative growth rate (RGR) of QPM

Source of variance	d. f.	MSS							
		CGR				RGR			
		30 – 60 DAS		60 DAS - At harvest		30 – 60 DAS		60 DAS - At harvest	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	0.0102	0.0047	0.6251	0.1425	0.00003	0.00002	0.00003	0.000004
Weed mgt. (W)	8	0.0167	0.0132	0.4550	0.4215	0.00039	0.00047	0.00000	0.000003
Error (a)	16	0.0518	0.0126	0.4112	0.3534	0.00002	0.00001	0.00002	0.000004
Nutrient mgt. (F)	2	0.0431	0.0051	1.1954	0.1579	0.00000	0.00002	0.00001	0.000003
W x F	16	0.0101	0.0126	1.1308	0.0123	0.00001	0.00000	0.00004	0.000002
Error (b)	36	0.0200	0.0136	0.3619	0.1775	0.00001	0.00001	0.00001	0.000006

* Significant at 5 % level of significance

Appendix XVII: Analysis of variance for days to 50% silking and yield attributes of QPM

Source of variance	d. f.	MSS					
		Days to 50% silking		Yield attributes			
				Number of grains cob^{-1}		Weight of grains (g plant^{-1})	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	9.77	9.08	217.04	293.57	5.965	8.40
Weed mgt. (W)	8	8.2	3.5	9944.9*	10498.6*	920.009*	542.1*
Error (a)	16	10.7	3.2	165.6	217.3	3.306	5.7
Nutrient mgt. (F)	2	0.9	0.6	562.6*	361.5*	23.529*	31.6*
W x F	16	1.30	1.91	244.98	77.60	0.375	0.19
Error (b)	36	3.37	2.14	122.68	109.68	1.895	2.67

* Significant at 5 % level of significance

Appendix XVIII: Analysis of variance for yield attributes of QPM

Source of variance	d. f.	MSS					
		Yield attributes					
		Number of cobs plant^{-1}		Test wt (g)		Shelling (%)	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.0169	0.110	16.72	9.78	36.785	21.391
Weed mgt. (W)	8	0.0533	0.040	3132.1*	3293.7*	60.837*	53.228*
Error (a)	16	0.0373	0.052	12.7	9.9	16.802	3.535
Nutrient mgt. (F)	2	0.0007	0.000	38.2*	51.6*	17.547*	8.499*
W x F	16	0.0011	0.000	8.86	1.91	1.900	0.840
Error (b)	36	0.0181	0.017	6.84	9.81	12.345	2.915

* Significant at 5 % level of significance

Appendix XIX: Analysis of variance for yields and harvest index of QPM

Source of variance	d. f.	MSS							
		Yield (kg ha^{-1})						Harvest index (%)	
		Grain		Stover		Biological			
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	191801.08	150299.53	132562.21	244931.68	535488.10	644147.70	4.0296	2.468
Weed mgt. (W)	8	3293643.5*	2903615.8*	7286443.59*	6367857.1*	20266264.9*	17800028.0*	5.0361	2.998
Error (a)	16	180904.7	147163.3	411827.74	208089.7	790076.2	459129.4	8.2546	5.299
Nutrient mgt. (F)	2	1078845.0*	281650.6*	3784548.21*	598512.7*	8748263.0*	1696150.0*	4.0687	0.125
W x F	16	152453.81	2171.59	237.89	150221.26	156283.03	143938.40	4.3710	2.018
Error (b)	36	132197.67	39751.39	132062.96	149223.22	270596.46	192820.07	6.3532	3.510

* Significant at 5 % level of significance

Appendix XX: Analysis of variance for chlorophyll content and protein content of QPM

Source of variance	d. f.	MSS					
		Chlorophyll content (mg g^{-1})				Protein content in grain (%)	
		30 DAS		60 DAS			
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.0018	0.0018	0.0019	0.00304	27.904	53.301
Weed mgt. (W)	8	0.0577*	0.0592*	0.0262*	0.03120*	386.24*	376.01*
Error (a)	16	0.0044	0.0044	0.0040	0.00208	78.078	64.901
Nutrient mgt. (F)	2	0.0357*	0.0354*	0.0152*	0.01513*	290.58*	293.01*
W x F	16	0.0067	0.0066	0.0034	0.00313	0.521	0.226
Error (b)	36	0.0034	0.0034	0.0027	0.00170	63.792	62.811

* Significant at 5 % level of significance

Appendix XXI: Analysis of variance for nutrient content in QPM

Source of variance	d. f.	MSS							
		N content (%)				P content (%)			
		Grain		Stover		Grain		Stover	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	0.00117	0.00339	0.00023	0.00068	0.00002	0.00005	0.00001	0.00002
Weed mgt. (W)	8	0.11152*	0.03851*	0.05428*	0.01484*	0.02633*	0.02300*	0.00021*	0.00015*
Error (a)	16	0.00911	0.00760	0.00149	0.00091	0.00021	0.00026	0.00004	0.00005
Nutrient mgt. (F)	2	0.01593*	0.01326*	0.00499*	0.00387*	0.00015*	0.00080*	0.00016*	0.00005*
W x F	16	0.00741	0.00854	0.00510	0.01005	0.00008	0.00045	0.00012	0.00003
Error (b)	36	0.00372	0.00372	0.00024	0.00070	0.00001	0.00020	0.00002	0.00001

* Significant at 5 % level of significance

Appendix XXII: Analysis of variance for nutrient content in QPM

Source of variance	d. f.	MSS							
		K content (%)				S content (%)			
		Grain		Stover		Grain		Stover	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	0.000008	0.000001	0.00211	0.00039	0.00002	0.00013	0.00001	0.00004
Weed mgt. (W)	8	0.002599*	0.003155*	0.00646	0.00312	0.00181*	0.00189*	0.00028*	0.00018*
Error (a)	16	0.000229	0.000232	0.00324	0.00433	0.00012	0.00014	0.00003	0.00004
Nutrient mgt. (F)	2	0.000131*	0.000524*	0.00037	0.00042	0.00180*	0.00264*	0.00035*	0.00037*
W x F	16	0.000124	0.000178	0.00047	0.00045	0.00192	0.00278	0.00021	0.00015
Error (b)	36	0.000014	0.000144	0.00220	0.00050	0.00012	0.00012	0.00002	0.00002

* Significant at 5 % level of significance

Appendix XXIII: Analysis of variance for nutrient uptake by QPM

Source of variance	d. f.	MSS					
		N uptake (kg ha^{-1})					
		Grain		Stover		Total	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	70.6506	22.3098	8.0754	26.7705	94.5480	76.1458
Weed mgt. (W)	8	1754.4679*	1325.2580*	1016.4125*	629.9758*	5424.7538*	3777.2040*
Error (a)	16	87.2563	84.1202	45.7055	14.9910	188.5011	115.6442
Nutrient mgt. (F)	2	563.2289*	166.4652*	324.8085*	101.9085*	1735.7581*	528.8672*
W x F	16	90.0127	6.7973	9.1154	55.9513	93.1184	62.5848
Error (b)	36	46.7630	19.5146	9.8794	17.0494	60.5885	31.9189

* Significant at 5 % level of significance

Appendix XXIV: Analysis of variance for nutrient uptake by QPM

Source of variance	d. f.	MSS					
		P uptake (kg ha^{-1})					
		Grain		Stover		Total	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	2.5859	3.5257	0.6300	0.7342	4.3108	5.3444
Weed mgt. (W)	8	161.6050*	152.4325*	26.0744*	24.7052*	315.9451*	299.6051*
Error (a)	16	3.5057	3.7565	1.8355	1.0851	7.3662	6.1936
Nutrient mgt. (F)	2	27.2739*	11.0651*	16.4270*	3.1781*	85.0998*	25.9804*
W x F	16	4.7265	0.3605	0.6906	0.7716	8.9548	1.8310
Error (b)	36	2.8057	0.6533	0.6350	0.5235	3.5828	1.3991

* Significant at 5 % level of significance

Appendix XXV: Analysis of variance for nutrient uptake by QPM

Source of variance	d. f.	MSS					
		K uptake (kg ha^{-1})					
		Grain		Stover		Total	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	3.6644	3.0700	56.4591	55.0731	78.6443	71.7082
Weed mgt. (W)	8	91.8431*	88.9534*	1733.4458*	1484.7155*	2601.4249*	2277.0734*
Error (a)	16	4.5782	3.6593	143.9742	79.1787	172.3870	93.4557
Nutrient mgt. (F)	2	28.0005*	10.9840*	786.4783*	144.1377*	1101.1610*	233.8193*
W x F	16	5.6016	0.3628	0.8424	35.2956	5.8507	38.6249
Error (b)	36	2.8668	0.6376	41.5225	33.5583	46.4012	35.0403

* Significant at 5 % level of significance

Appendix XXVI: Analysis of variance for nutrient uptake by QPM

Source of variance	d. f.	MSS					
		S uptake (kg ha^{-1})					
		Grain		Stover		Total	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	2.4371	2.0019	0.3559	0.5634	3.7785	3.4041
Weed mgt. (W)	8	49.9616*	47.9160*	15.8765*	13.6626*	121.9014*	112.4706*
Error (a)	16	2.3121	1.7673	0.9681	0.3943	4.9174	2.8846
Nutrient mgt. (F)	2	20.5905*	9.4670*	12.4895*	4.1983*	64.8649*	26.2694*
W x F	16	2.4746	1.8935	1.1454	0.9499	6.4219	4.4157
Error (b)	36	1.7461	0.3990	0.3489	0.3279	2.4780	0.9417

* Significant at 5 % level of significance

Appendix XXVII: Analysis of variance for soil pH and EC

Source of variance	d. f.	MSS							
		Soil pH				Soil EC (dsm^{-1})			
		30 DAS		At harvest		30 DAS		At harvest	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	0.06214	0.05165	0.05069	0.00971	0.00205	0.00075	0.00184	0.00056
Weed mgt. (W)	8	0.01022	0.00732	0.00727	0.00685	0.00184	0.00264	0.00246	0.00128
Error (a)	16	0.08309	0.09464	0.09334	0.01594	0.00294	0.00107	0.00306	0.00102
Nutrient mgt. (F)	2	0.00008	0.00010	0.00007	0.00000	0.00002	0.00058	0.00001	0.00028
W x F	16	0.00009	0.00009	0.00009	0.00000	0.00002	0.00040	0.00001	0.00032
Error (b)	36	0.06734	0.07332	0.07161	0.00333	0.00227	0.00079	0.00120	0.00080

* Significant at 5 % level of significance

Appendix XXVIII: Analysis of variance for soil organic carbon and available nutrient in soil at harvest

Source of variance	d. f.	MSS					
		Organic carbon (g kg^{-1})		Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.2878	0.2586	88.9544	4.9002	21.9238	9.1555
Weed mgt. (W)	8	1.6612	1.0246	464.0402	1126.9876	28.8916	19.1519
Error (a)	16	0.7168	0.4721	782.3226	1074.6916	12.8409	8.0944
Nutrient mgt. (F)	2	0.0646	0.0599	49.3934	2.1875	0.0519	0.0297
W x F	16	0.0605	0.0099	47.0610	3.5454	0.0301	0.0382
Error (b)	36	0.1766	0.1687	278.1270	243.8681	1.8613	3.0712

* Significant at 5 % level of significance

Appendix XXIX: Analysis of variance for available nutrient in soil at harvest

Source of variance	d. f.	MSS			
		Available potassium (kg ha^{-1})		Available sulphur (kg ha^{-1})	
		2015	2016	2015	2016
Replication (R)	2	9.7005	1812.5226	4.2889	5.5929
Weed mgt. (W)	8	4009.3435	2018.5759	10.2286	11.1438
Error (a)	16	2913.4983	2915.5748	4.9880	6.4543
Nutrient mgt. (F)	2	4.8768	37.9963	0.4157	0.8886
W x F	16	6.8993	34.8793	0.4879	1.3130
Error (b)	36	663.5707	930.7969	1.7090	1.6930

* Significant at 5 % level of significance

Appendix XXX: Analysis of variance for soil enzyme activity at harvest of QPM

Source of variance	d. f.	MSS					
		Soil enzyme activity					
		Dehydrogenase		Phosphatase		Urease	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	171.443	545.249	1067.226	3158.006	813.327	3707.958
Weed mgt. (W)	8	549.599	308.462	1971.574	2089.489	2873.150	1636.007
Error (a)	16	234.849	408.087	795.604	1205.537	1226.730	2877.199
Nutrient mgt. (F)	2	71.044	104.822	23.060	219.442	20.252	557.838
W x F	16	44.635	22.076	57.169	105.560	174.284	216.245
Error (b)	36	48.824	221.915	170.703	183.623	383.037	1095.968

* Significant at 5 % level of significance

Appendix XXXI: Analysis of variance for net return and B:C ratio of QPM

Source of variance	d. f.	MSS			
		Net return		B:C ratio	
		2015	2016	2015	2016
Replication (R)	2	59598755.91	554447999.26	0.09849	0.08382
Weed mgt. (W)	8	1083869662	1015402730.1	1.34339	1.14629
Error (a)	16	58381331.0	47079890.1	0.09864	0.06778
Nutrient mgt. (F)	2	256316937.0	16330432.7	0.62167	0.75030
W x F	16	39190932.53	1524710.82	0.05509	0.00478
Error (b)	36	35161821.72	12355675.66	0.05185	0.01610

* Significant at 5 % level of significance

Appendix XXXII: Analysis of variance for weed density at 30 DAS in succeeding wheat

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Phalaris minor		*Avena fatua*		*Amaranthus viridis*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	27.1430	2.1720	0.1437	0.1785	4.8994	1.3879
Weed mgt. (W)	8	1.3122	1.2260	0.1058	0.0898	2.8328	8.9949
Error (a)	16	1.4876	1.3524	0.0863	0.1069	9.8098	7.5948
Nutrient mgt. (F)	2	0.4853	0.0431	0.0023	0.0058	8.1628	0.0200
W x F	16	0.1612	0.1659	0.0424	0.0152	6.1960	0.1396
Error (b)	36	1.0758	0.5914	0.0293	0.0411	3.5906	2.5110

* Significant at 5 % level of significance

Appendix XXXIII: Analysis of variance for weed density at 30 DAS in succeeding wheat

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Anagallis arvensis		*Chenopodium album*		*Chenopodium murale*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.5724	0.0350	9.5167	18.1451	21.5097	13.1684
Weed mgt. (W)	8	0.5496	0.1153	2.2515	12.3521	26.0137	3.5361
Error (a)	16	0.2305	0.2086	4.7447	8.1279	13.6709	8.0374
Nutrient mgt. (F)	2	0.0232	0.0188	0.0652	1.8500	5.9314	0.0227
W x F	16	0.0982	0.0720	0.0048	0.5406	3.8476	0.0797
Error (b)	36	0.0567	0.0781	1.8512	1.3465	5.8420	1.9019

* Significant at 5 % level of significance

Appendix XXXIV: Analysis of variance for weed density at 30 DAS in succeeding wheat

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Convolvlous arvensis		*Melilotus indica*		*Malva parviflora*	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	0.2241	7.6143	0.1109	0.9751	0.1990	0.1141
Weed mgt. (W)	8	20.2364	34.8310	0.4158	0.9053	1.1319	0.9225
Error (a)	16	8.2462	16.9623	0.2931	0.3977	0.6428	0.4537
Nutrient mgt. (F)	2	0.2247	9.3575	0.0730	0.2785	0.2955	0.0027
W x F	16	0.0169	24.6733	0.1106	0.4902	0.7914	0.0124
Error (b)	36	1.7462	5.3339	0.1895	0.3076	0.3237	0.1428

* Significant at 5 % level of significance

Appendix XXXV: Analysis of variance for weed density at 30 DAS in succeeding wheat

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	34.3607	7.7004	235.3786	157.8636	419.9804	235.2921
Weed mgt. (W)	8	2.0848	1.3479	82.4958	150.1434	98.2459	170.9654
Error (a)	16	2.4784	3.5693	127.6740	112.6058	139.7717	149.3878
Nutrient mgt. (F)	2	0.4459	0.0690	12.7747	18.1734	17.3780	19.4883
W x F	16	0.2363	0.2134	11.5719	24.9033	11.9499	24.6697
Error (b)	36	1.0951	0.8247	69.7132	40.7268	77.7159	35.4663

* Significant at 5 % level of significance

Appendix XXXVI: Analysis of variance for weed dry matter at 30 DAS in succeeding wheat

Source of variance	d. f.	MSS					
		Weed dry matter (g m^{-2})					
		Narrow-leaved weeds		Broad-leaved weeds		Total weeds	
		2015	2016	2015	2016	2015	2016
Replication (R)	2	3.0549	1.8604	19.8953	4.8885	37.7414	7.1341
Weed mgt. (W)	8	0.9764	1.0868	8.2950	8.5169	8.1643	8.5966
Error (a)	16	2.7548	2.8126	18.2002	15.2077	33.8985	14.9894
Nutrient mgt. (F)	2	0.4146	0.5665	1.7148	1.9689	3.7930	4.6114
W x F	16	1.2445	1.4198	2.4534	2.5388	3.8135	4.0616
Error (b)	36	1.7639	1.6007	7.6015	16.2492	12.8683	21.0544

* Significant at 5 % level of significance

Appendix XXXVII: Analysis of variance for plant height and dry matter of succeeding wheat

Source of variance	d. f.	MSS							
		Plant height (cm)				Dry matter accumulation (g plant^{-1})			
		30 DAS		At harvest		30 DAS		At harvest	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	15.0396	14.9308	1.5958	0.0551	4.7728	5.3781	81.2160	232.1507
Weed mgt. (W)	8	11.4353	3.8195	2.4487	0.8158	1.7268	2.5555	8.7857	5.9839
Error (a)	16	4.8434	7.2592	2.3997	0.9318	2.8355	2.6877	109.7758	258.4608
Nutrient mgt. (F)	2	1.3373	0.4096	0.6980	0.6762	0.1240	0.6366	4.1348	0.1126
W x F	16	8.3005	1.1811	2.6665	0.9914	1.7164	1.5351	6.8451	1.0687
Error (b)	36	1.8054	1.4620	3.2162	0.6533	1.1701	1.2265	88.0922	151.4645

* Significant at 5 % level of significance

Appendix XXXVIII: Analysis of variance for yield attributes of succeeding wheat

Source of variance	d. f.	MSS							
		Yield attributes							
		Number of tillers metre^{-1} row length		Spike length (cm)		Number of grain spike^{-1}		1000-grain weight (g)	
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	7.7254	6.6464	1.5667	1.2486	6.9321	7.1943	9.5968	2.2651
Weed mgt. (W)	8	2.0441	0.2999	1.2842	1.6302	11.4381	8.4265	10.0111	9.8644
Error (a)	16	14.5843	5.6798	1.0351	1.4098	9.5261	9.8042	9.1247	12.4095
Nutrient mgt. (F)	2	1.1408	1.1004	0.5262	0.3405	2.0411	2.0505	1.2390	3.4029
W x F	16	1.4714	0.3502	1.0231	0.9231	7.3884	3.5565	6.4776	6.6999
Error (b)	36	11.0537	5.0639	0.9661	1.1196	2.7282	2.6524	5.0604	4.5104

* Significant at 5 % level of significance

Appendix XXXIX: Analysis of variance for yields and harvest index of succeeding wheat

Source of variance	d. f.	MSS							
		Yield (kg ha^{-1})						Harvest index (%)	
		Grain		Straw		Biological			
		2015	2016	2015	2016	2015	2016	2015	2016
Replication (R)	2	95890.67	74079.15	2229.33	220174.31	71987.98	307932.14	4.7970	7.5524
Weed mgt. (W)	8	107668.76	198579.15	56053.47	148262.66	255744.78	280617.90	2.5607	13.3461
Error (a)	16	129166.60	116008.93	230347.72	93222.69	274274.04	142575.49	13.2592	8.9420
Nutrient mgt. (F)	2	30495.61	12539.23	102844.82	49898.31	183932.37	52052.27	2.3480	2.3045
W x F	16	106647.93	244556.98	20113.77	26404.83	132061.93	303572.32	4.3725	8.8082
Error (b)	36	73038.41	78042.04	50412.34	47417.50	122948.75	116547.44	4.0734	4.4854

* Significant at 5 % level of significance

Appendix XL: Pooled analysis of variance for weed density at 30 DAS

Source of variance	d.f.	MSS								
		Weed density (No. m^{-2})								
		Echinochloa colona	*Cynodon dactylon*	*Cyperus rotundus*	*Dinebra retroflexa*	*Brachiaria reptans*	*Amaranthus viridis*	*Digera arvensis*	*Trianthema portulacastrum*	*Commelina benghalensis*
YEAR	1	96.96	2.71	2.64	16.50	5.85	32.08	5.93	0.26	40.79
Y X R	4	4.37	0.50	0.57	0.57	0.25	0.19	0.50	3.29	1.63
weed mgt. (W)	8	10252.23*	89.54*	70.25*	1097.39*	137.04*	148.04*	86.26*	1354.35*	688.10*
W x Y	8	65.18	0.06	0.14	2.71	0.21	5.12	0.28	12.69	16.55
Pooled error (a)	32	5.22	0.44	0.85	0.85	0.87	1.21	0.72	5.67	1.38
Nutrient mgt.	2	0.54	0.18	0.79	0.79	0.77	1.44	0.08	0.57	0.45
F X Y	2	0.15	0.00	0.38	0.38	0.37	0.00	0.06	0.11	0.28
W x F	16	0.59	0.17	0.20	0.20	0.20	0.41	0.23	0.71	0.18
Y X W X F	16	0.29	0.02	0.08	0.08	0.08	0.00	0.28	0.28	0.15
Pooled error (b)	72	1.25	0.28	0.70	0.70	0.75	1.19	0.32	4.14	1.04

* Significant at 5 % level of significance

Appendix XLI: Pooled analysis of variance for weed density at 60 DAS

Source of variance	d.f.	MSS								
		Weed density (No. m^{-2})								
		Echinochloa colona	*Cynodon dactylon*	*Cyperus rotundus*	*Dinebra retroflexa*	*Brachiaria reptans*	*Amaranthus viridis*	*Digera arvensis*	*Trianthema portulacastrum*	*Commelina benghalensis*
YEAR	1	50.77	14.86	5.35	14.53	0.32	17.33	15.06	25.09	72.23
Y X R	4	8.53	6.34	1.58	1.36	0.60	0.52	1.93	1.06	5.68
weed mgt. (W)	8	13987.01*	289.70*	205.85*	1819.80*	326.58*	331.04*	390.11*	1853.15*	1052.66*
W x Y	8	28.99	4.39	0.64	4.84	4.44	2.13	2.16	16.01	28.03
Pooled error (a)	32	8.59	1.82	2.02	2.28	1.28	1.42	2.73	3.61	2.43
Nutrient mgt.	2	0.29	0.59	0.02	0.28	0.02	0.11	0.19	0.23	0.06
F X Y	2	0.03	0.36	0.02	0.06	0.00	0.03	0.01	0.14	0.06
W x F	16	0.09	0.16	0.23	0.17	0.42	0.14	0.18	0.13	0.13
Y X W X F	16	0.15	0.10	0.07	0.07	0.00	0.05	0.06	0.21	0.17
Pooled error (b)	72	1.38	1.64	1.76	2.23	0.73	0.73	2.58	1.42	2.19

* Significant at 5 % level of significance

Appendix XLII: Pooled analysis of variance for weed density at 30 and 60 DAS

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})					
		30 DAS			60 DAS		
		Narrow-leaved weeds	Broad-leaved weeds	Total weeds	Narrow-leaved weeds	Broad-leaved weeds	Total weeds
YEAR	1	384.10	195.27	1127.12	273.54	464.47	1450.91
Y X R	4	11.26	8.38	15.26	53.38	16.40	122.13
weed mgt. (W)	8	26363.91*	6960.00*	60316.35*	43868.60*	12762.84*	103806.37*
W x Y	8	110.15	76.91	349.90	68.98	145.84	414.28
Pooled error (a)	32	13.85	14.96	45.82	40.77	24.15	114.94
Nutrient mgt.	2	9.53	6.51	30.28	2.85	0.23	2.14
F X Y	2	2.72	0.74	6.30	0.99	0.06	0.55
W x F	16	2.71	1.50	5.85	1.85	0.79	4.28
Y X W X F	16	1.13	0.61	2.52	0.39	0.61	1.12
Pooled error (b)	72	7.27	5.94	18.78	8.88	6.71	20.15

* Significant at 5 % level of significance

Appendix XLIII: Pooled analysis of variance for weed dry matter at 30, 60 DAS and at harvest

Source of variance	d.f.	MSS								
		Weed dry matter (g m^{-2})								
		30 DAS			60 DAS			At harvest		
		Narrow-leaved weeds	Broad-leaved weeds	Total weeds	Narrow-leaved weeds	Broad-leaved weeds	Total weeds	Narrow-leaved weeds	Broad-leaved weeds	Total weeds
YEAR	1	9.52	21.12	59.00	413.59	624.66	2054.82	324.51	541.70	1704.75
Y X R	4	0.84	0.84	3.35	11.32	2.45	18.84	6.77	4.65	8.44
weed mgt. (W)	8	2480.03*	2374.37*	9705.75*	23107.43*	17732.60*	80650.68*	55019.01*	52657.63*	215288.38*
W x Y	8	3.77	7.50	21.50	68.64	89.90	213.60	29.95	36.80	119.99
Pooled error (a)	32	1.38	1.38	5.51	13.34	1.77	15.78	12.49	26.34	61.43
Nutrient mgt.	2	0.18	0.18	0.70	31.78*	25.01*	112.77*	25.27*	39.63*	127.76*
F X Y	2	0.07	0.07	0.29	0.30	0.01	0.19	0.23	0.01	0.16
W x F	16	0.06	0.06	0.26	0.05	0.04	0.19	0.44	0.92	2.41
Y X W X F	16	0.07	0.07	0.27	0.01	0.01	0.03	0.08	0.02	0.10
Pooled error (b)	72	1.22	1.22	4.86	4.15	0.86	4.89	3.60	4.37	8.68

* Significant at 5 % level of significance

Appendix XLIV: Pooled analysis of variance for nutrient content in weeds at harvest

Source of variance	d. f.	MSS			
		Content (%)			
		N	P	K	S
YEAR	1	0.006412	0.000101	0.000016	0.000465
Y X R	4	0.000866	0.000094	0.001910	0.000074
weed mgt. (W)	8	0.000030	0.000331	0.000648	0.000211
W x Y	8	0.000004	0.000305	0.000187	0.000029
Pooled error (a)	32	0.002733	0.000163	0.004362	0.000112
Nutrient mgt.	2	0.004861	0.000001	0.001293	0.007066*
F X Y	2	0.000751	0.000001	0.000157	0.000004
W x F	16	0.004189	0.000000	0.001209	0.000365
Y X W X F	16	0.000779	0.000001	0.000150	0.000002
Pooled error (b)	72	0.001619	0.000088	0.001866	0.000068

* Significant at 5 % level of significance

Appendix XLV: Pooled analysis of variance for nutrient uptake by weeds at harvest

Source of variance	d. f.	MSS			
		Nutrient uptake (kg ha^{-1})			
		N uptake	P uptake	K uptake	S uptake
YEAR	1	14.62	1.4404	43.85	0.076
Y X R	4	1.89	0.2591	3.26	0.157
weed mgt. (W)	8	3766.96*	137.4147*	5877.50*	70.009*
W x Y	8	1.63	0.2162	3.17	0.023
Pooled error (a)	32	4.23	0.3153	6.40	0.196
Nutrient mgt.	2	1.24	0.0735	1.95	2.097*
F X Y	2	0.12	0.0003	0.02	0.001
W x F	16	1.01	0.0020	0.13	0.334
Y X W X F	16	0.15	0.0002	0.01	0.001
Pooled error (b)	72	0.66	0.0795	0.66	0.053

* Significant at 5 % level of significance

Appendix XLVI: Pooled analysis of variance for plant population, plant height, and dry matter of QPM

Source of variance	d. f.	MSS						
		Plant population		Plant height (cm)		Dry matter accumulation (g plant $^{-1}$)		
		30 DAS	At harvest	30 DAS	At harvest	30 DAS	60 DAS	At harvest
YEAR	1	0.379	14.572	448.46	808.95	41.09	76.22	279.84
Y X R	4	2.826	14.722	20.01	45.91	7.52	16.21	253.42
weed mgt. (W)	8	3.964	9.108	814.13*	5535.75*	545.21*	1159.62*	5663.96*
W x Y	8	0.386	0.779	15.10	14.35	2.28	0.43	27.56
Pooled error (a)	32	4.182	23.965	14.70	235.83	2.19	36.62	232.74
Nutrient mgt.	2	3.998	2.720	143.50*	532.27*	35.56*	134.25*	1999.72*
F X Y	2	2.670	0.896	16.11	0.41	0.39	6.81	359.93
W x F	16	1.834	1.132	93.14	48.53	1.41	9.28	489.79
Y X W X F	16	0.999	0.674	79.98	0.10	1.14	7.01	493.22
Pooled error (b)	72	3.116	6.652	10.47	80.65	1.84	12.88	201.47

* Significant at 5 % level of significance

Appendix XLVII: Pooled analysis of variance for CGR and RGR of QPM

Source of variance	d. f.	MSS			
		CGR		RGR	
		30 - 60 DAS	60 – At harvest	30 - 60 DAS	60 – At harvest
YEAR	1	0.0067353	0.0716918	0.0000256	0.0000001
Y X R	4	0.0074321	0.3837910	0.0000247	0.0000152
weed mgt. (W)	8	0.0298752	0.8764758	0.0008613	0.0000082
W x Y	8	0.0038467	0.0279183	0.0000044	0.0000007
Pooled error (a)	32	0.0322170	0.3823357	0.0000166	0.0000110
Nutrient mgt.	2	0.0482333	1.3533301	0.0000234	0.0000167
F X Y	2	0.0107528	0.3288214	0.0000041	0.0000066
W x F	16	0.0158578	0.5545171	0.0000081	0.0000181
Y X W X F	16	0.0067800	0.5885532	0.0000034	0.0000208
Pooled error (b)	72	0.0168028	0.2697091	0.0000103	0.0000089

* Significant at 5 % level of significance

Appendix XLVIII: Pooled analysis of variance for days to 50% silking and yield attributes of QPM

Source of variance	d. f.	MSS					
		Days to 50% silking	Yield attributes				
			Number of grains cob^{-1}	Weight of grains (g $plant^{-1}$)	Number of cobs $plant^{-1}$	Test wt (g)	Shelling (%)
YEAR	1	5.65	2100.24	48.12	0.0293	601.16	2.357
Y X R	4	9.43	255.31	7.18	0.0636	13.25	29.088
weed mgt. (W)	8	11.72	20443.53*	1462.10*	0.0320	6425.79*	114.065*
W x Y	8	6.05	70.47	36.75	0.0009	53.74	1.107
Pooled error (a)	32	6.97	191.42	4.51	0.0448	11.32	10.168
Nutrient mgt.	2	1.48	924.11*	55.17*	0.0008	89.79*	26.045*
F X Y	2	0.38	45.48	1.29	0.0004	2.96	0.819
W x F	16	1.32	191.61	0.30	0.0005	7.15	2.450
Y X W X F	16	1.88	130.97	0.26	0.0011	3.62	0.290
Pooled error (b)	72	2.76	116.18	2.28	0.0178	8.33	7.630

* Significant at 5 % level of significance

Appendix XLIX: Pooled analysis of variance for yield and harvest index of QPM

Source of variance	d. f.	MSS			
		Yield (kg ha^{-1})			Harvest index (%)
		Grain	Stover	Biological	
YEAR	1	352787.27	1267975.46	2958410.82	0.00052
Y X R	4	171050.31	188746.95	589817.90	3.24875
weed mgt. (W)	8	6197259.22*	13654300.71*	38066292.94*	8.03414
W x Y	8	17642.49	57142.16	117803.61	0.42792
Pooled error (a)	32	164033.98	309958.74	624602.82	6.77668
Nutrient mgt.	2	1360495.61*	4383060.88*	10444413.07*	4.19363
F X Y	2	147778.38	996102.39	1861136.04	2.72995
W x F	16	77307.06	73327.59	180018.48	2.86335
Y X W X F	16	77318.34	77131.56	120202.94	3.52536
Pooled error (b)	72	85974.53	140643.09	231708.26	4.93156

* Significant at 5 % level of significance

Appendix L: Pooled analysis of variance for chlorophyll content and protein content of QPM

Source of variance	d. f.	MSS		
		Chlorophyll content (mg g^{-1} f.w.)		Protein content in grain (%)
		30 DAS	60 DAS	
YEAR	1	0.004434	0.000718	0.2124
Y X R	4	0.001805	0.002449	0.0890
weed mgt. (W)	8	0.116978*	0.057363*	5.8606*
W x Y	8	0.000110	0.000785	0.4202
Pooled error (a)	32	0.004379	0.003024	0.3264
Nutrient mgt.	2	0.071106*	0.030344*	1.1404*
F X Y	2	0.000000	0.000000	0.2010
W x F	16	0.006250	0.003804	0.2962
Y X W X F	16	0.000000	0.000000	0.3271
Pooled error (b)	72	0.003436	0.002184	0.1453

* Significant at 5 % level of significance

Appendix LI: Pooled analysis of variance for nutrient content in QPM

Source of variance	d. f.	MSS			
		Content (%)			
		N		P	
		Grain	Stover	Grain	Stover
YEAR	1	0.005437	0.012960	0.006750	0.003283
Y X R	4	0.002279	0.000455	0.000037	0.000016
weed mgt. (W)	8	0.150032*	0.069125*	0.049337*	0.000361*
W x Y	8	0.010757	0.007203	0.000335	0.000005
Pooled error (a)	32	0.008357	0.001199	0.000236	0.000043
Nutrient mgt.	2	0.029195*	0.008858*	0.000946*	0.000210*
F X Y	2	0.005145	0.000771	0.000144	0.000018
W x F	16	0.007581	0.007047	0.000430	0.000128
Y X W X F	16	0.008374	0.008103	0.000098	0.000020
Pooled error (b)	72	0.003720	0.000467	0.000106	0.000019

* Significant at 5% level of significance

Appendix LII: Pooled analysis of variance for nutrient content in QPM

Source of variance	d. f.	MSS			
		Content (%)			
		K		S	
		Grain	Stover	Grain	Stover
YEAR	1	0.002620	0.006341	0.00075	0.00006
Y X R	4	0.000004	0.001255	0.00008	0.00002
weed mgt. (W)	8	0.005754*	0.009583	0.00370*	0.00046*
W x Y	8	0.000071	0.000333	0.00004	0.00001
Pooled error (a)	32	0.000231	0.003782	0.00013	0.00003
Nutrient mgt.	2	0.000654*	0.000797	0.00445*	0.00072*
F X Y	2	0.000066	0.000001	0.00004	0.00001
W x F	16	0.000270	0.000915	0.00466	0.00024
Y X W X F	16	0.000032	0.000002	0.00004	0.00012
Pooled error (b)	72	0.000079	0.001350	0.00012	0.00002

* Significant at 5% level of significance

Appendix LIII: Pooled analysis of variance for nutrient uptake by QPM

Source of variance	d. f.	MSS					
		N uptake (kg ha^{-1})			P uptake (kg ha^{-1})		
		Grain	Stover	Total	Grain	Stover	Total
YEAR	1	39.2311	0.1287	34.8656	33.2971	33.4127	133.4196
Y X R	4	46.4802	17.4229	85.3469	3.0558	0.6821	4.8276
weed mgt. (W)	8	3079.7259*	1646.3883*	9201.9578*	314.0375*	50.7795*	615.5502*
W x Y	8	20.4634	27.7086	88.4427	0.9969	0.1136	1.0632
Pooled error (a)	32	85.6883	30.3483	152.0726	3.6311	1.4603	6.7799
Nutrient mgt.	2	729.6940*	426.7170*	2264.6252**	38.3391*	19.6051*	111.0802*
F X Y	2	77.8287	52.7901	254.9544	1.9672	3.4430	10.3785
W x F	16	51.7871	35.0803	135.4733	3.3778	1.1949	8.1490
Y X W X F	16	45.0228	29.9864	20.2299	1.7091	0.2673	2.6368
Pooled error (b)	72	33.1388	13.4644	46.2537	1.7295	0.5792	2.4910

* Significant at 5 % level of significance

Appendix LIV: Pooled analysis of variance for nutrient uptake by QPM

Source of variance	d. f.	MSS					
		K uptake (kg ha^{-1})			S uptake (kg ha^{-1})		
		Grain	Stover	Total	Grain	Stover	Total
YEAR	1	21.9392	438.9848	657.1991	8.8938	3.1307	22.5779
Y X R	4	3.3672	55.7661	75.1763	2.2195	0.4597	3.5913
weed mgt. (W)	8	180.7965*	3218.1612*	4878.4983*	97.8776*	29.5391*	234.3719*
W x Y	8	0.5195	12.7089	17.1893	0.3269	0.1355	0.7829
Pooled error (a)	32	4.1187	111.5765	132.9213	2.0397	0.6812	3.9010
Nutrient mgt.	2	38.9845*	930.6160*	1334.9803*	30.0575*	16.6878*	91.1343*
F X Y	2	2.4979	199.3755	244.9520	1.2005	1.3187	5.0005
W x F	16	4.1646	20.2808	28.2554	3.3512	1.4018	7.8974
Y X W X F	16	1.7997	15.8571	16.2202	1.0168	0.6935	2.9402
Pooled error (b)	72	1.7522	37.5404	40.7207	1.0726	0.3384	1.7098

* Significant at 5 % level of significance

Appendix LV: Pooled analysis of variance for soil pH, EC and organic carbon of QPM

Source of variance	d. f.	MSS				
		Soil pH		Soil EC		Organic carbon (g kg^{-1})
		30 DAS	At harvest	30 DAS	At harvest	
YEAR	1	0.00026	0.01635	0.00016	0.00172	0.18674
Y X R	4	0.05690	0.03020	0.00140	0.00120	0.27324
weed mgt. (W)	8	0.01753	0.01412	0.00447	0.00374	2.68580
W x Y	8	0.00066	0.00033	0.00104	0.00043	0.04426
Pooled error (a)	32	0.08886	0.05464	0.00201	0.00204	0.59444
Nutrient mgt.	2	0.00017	0.00008	0.00059	0.00029	0.12442
F X Y	2	0.00000	0.00004	0.00020	0.00010	0.12083
W x F	16	0.00017	0.00005	0.00022	0.00016	0.02810
Y X W X F	16	0.00000	0.00004	0.00020	0.00017	0.04224
Pooled error (b)	72	0.07033	0.03747	0.00153	0.00100	0.17264

* Significant at 5 % level of significance

Appendix LVI: Pooled analysis of variance for available nutrient in soil at harvest

Source of variance	d. f.	MSS			
		Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available sulphur (mg kg^{-1})
YEAR	1	242.78559	9.54843	87.44894	2.24285
Y X R	4	46.92731	15.53960	911.11157	4.94090
weed mgt. (W)	8	1591.02782	48.04348	6027.91934	12.99750
W x Y	8	95.14668	1.14348	212.14112	0.29096
Pooled error (a)	32	928.50713	10.46765	2914.53651	5.72119
Nutrient mgt.	2	51.58096	0.08158	42.87312	1.30424
F X Y	2	15.50339	0.00520	10.25825	0.07513
W x F	16	37.58812	0.05663	34.88437	1.67262
Y X W X F	16	13.01825	0.01166	6.89422	0.12824
Pooled error (b)	72	260.99756	2.46628	797.18379	1.70104

* Significant at 5% level of significance

Appendix LVII: Pooled analysis of variance for soil enzyme activity at harvest of QPM

Source of variance	d. f.	MSS		
		Soil enzyme activity		
		Dehydrogenase	Phosphatase	Urease
YEAR	1	897.8122	3026.2229	8193.1225
Y X R	4	358.3461	2112.6157	2260.6425
weed mgt. (W)	8	800.0000	2511.0000	4509.1572
W x Y	8	194.9846	592.2479	1675.2214
Pooled error (a)	32	321.4679	1000.5707	2051.9644
Nutrient mgt.	2	175.8659	242.5024	578.0902
F X Y	2	1.6537	131.4656	191.3166
W x F	16	21.6617	69.5615	34.7743
Y X W X F	16	45.0492	93.1672	355.7550
Pooled error (b)	72	135.3694	177.1633	739.5025

* Significant at 5 % level of significance

Appendix LVIII: Pooled analysis of variance for net return and B:C ratio of QPM

Source of variance	d. f.	MSS	
		Net return	B:C ratio
YEAR	1	963954745.12	0.7462
Y X R	4	57521777.59	0.0912
weed mgt. (W)	8	2099272392.33*	2.4897
W x Y	8	4874303.05	0.0102
Pooled error (a)	32	52730610.57	0.0832
Nutrient mgt.	2	272647369.62*	1.3720
F X Y	2	73764729.60	0.1137
W x F	16	21867128.96	0.0301
Y X W X F	16	18848514.38	0.0298
Pooled error (b)	72	23758748.69	0.0340

* Significant at 5% level of significance

Appendix LIX: Pooled analysis of variance for weed density at 30 DAS in succeeding wheat

Source of variance	d.f.	MSS								
		Weed density (No. m^{-2})								
		Phalaris minor	*Avena fatua*	*Amaranthus viridis*	*Anagallis arvensis*	*Chenopodium album*	*Chenopodium murale*	*Convolvlous arvensis*	*Melilotus indica*	*Malva parviflora*
YEAR	1	2.7851	0.2381	161.1313	0.1527	62.9961	71.9783	100.3522	12.7045	97.9731
Y X R	4	14.6575	0.1611	3.1436	0.3037	13.8309	17.3390	3.9192	0.5430	0.1565
weed mgt. (W)	8	1.3122	0.1058	2.8328	0.5496	2.2515	26.0137	20.2364	0.4158	1.1319
W x Y	8	0.9377	0.0498	5.5181	0.3596	4.8265	15.1977	23.8861	0.4238	0.6159
Pooled error (a)	32	0.7438	0.0431	4.9049	0.2195	6.4363	10.8542	12.6043	0.3454	0.5483
Nutrient mgt.	2	0.4853	0.0023	8.1628	0.0232	0.0652	5.9314	0.2247	0.0730	0.2955
F X Y	2	0.1229	0.0076	4.4885	0.0034	0.6105	2.9116	3.8917	0.2008	0.1442
W x F	16	0.1459	0.0291	3.3571	0.0673	0.2775	2.0275	12.3860	0.3015	0.3655
Y X W X F	16	0.1813	0.0285	2.9785	0.1029	0.2679	1.8999	12.3041	0.2992	0.4383
Pooled error (b)	72	0.8336	0.0352	3.0508	0.0674	1.5989	3.8719	3.5401	0.2485	0.2332

* Significant at 5 % level of significance

Appendix LX: Pooled analysis of variance for weed density and weed dry matter at 30 DAS in succeeding wheat

Source of variance	d. f.	MSS					
		Weed density (No. m^{-2})			Weed dry matter (g m^{-2})		
		Narrow-leaved weeds	Broad-leaved weeds	Total weeds	Narrow-leaved weeds	Broad-leaved weeds	Total weeds
YEAR	1	4.6562	113.0014	163.5335	787.2409	626.4977	2818.3092
Y X R	4	21.0305	196.6211	327.6362	2.4576	12.3919	22.4377
weed mgt. (W)	8	2.0848	82.4958	98.2459	0.9764	8.2950	8.1643
W x Y	8	1.0649	35.3345	32.8259	0.0047	0.0032	0.0034
Pooled error (a)	32	1.2392	63.8370	69.8859	1.3774	9.1001	16.9492
Nutrient mgt.	2	0.4459	12.7747	17.3780	0.4146	1.7148	3.7930
F X Y	2	0.0825	1.4167	1.6703	0.0061	0.0065	0.0229
W x F	16	0.1710	21.0722	20.2529	2.6586	4.9887	7.8625
Y X W X F	16	0.2787	15.4030	16.3667	0.0057	0.0034	0.0126
Pooled error (b)	72	0.9599	55.2200	56.5911	1.6823	11.9254	16.9613

* Significant at 5 % level of significance

Appendix LXI: Pooled analysis of variance for plant height and dry matter of succeeding wheat

Source of variance	d. f.	MSS			
		Plant height (cm)		Dry matter accumulation (g $plant^{-1}$)	
		30 DAS	At harvest	30 DAS	At harvest
YEAR	1	15.8372	6.7497	0.7520	45.2766
Y X R	4	14.9852	0.8254	5.0754	156.6834
weed mgt. (W)	8	3.9485	2.4487	1.7268	5.9839
W x Y	8	5.8811	2.5390	3.7410	6.8836
Pooled error (a)	32	2.4217	1.1999	1.4177	129.2304
Nutrient mgt.	2	1.3373	0.6980	0.1240	0.1126
F X Y	2	1.4216	1.3549	0.4862	2.8011
W x F	16	4.3206	2.0461	1.9751	3.8331
Y X W X F	16	5.1610	1.6118	1.2764	4.0807
Pooled error (b)	72	1.6337	1.9347	1.1983	119.7783

* Significant at 5 % level of significance

Appendix LXII: Pooled analysis of variance for yield attributes of succeeding wheat

Source of variance	d. f.	MSS			
		Yield attributes			
		Number of tillers metre^{-1} row length	Spike length (cm)	Number of grain spike^{-1}	1000-grain weight (g)
YEAR	1	0.3794	0.0044	5.3272	13.0239
Y X R	4	7.1859	1.4077	7.0632	5.9309
weed mgt. (W)	8	2.0441	1.2842	11.4381	10.0111
W x Y	8	1.5077	1.1411	11.4354	0.0175
Pooled error (a)	32	7.2921	0.5176	4.7630	4.5624
Nutrient mgt.	2	1.1408	0.5262	2.0411	1.2390
F X Y	2	0.3335	0.0107	3.5237	0.3503
W x F	16	0.7155	1.1356	2.8516	13.1592
Y X W X F	16	1.1061	0.8107	8.0933	0.0183
Pooled error (b)	72	8.0588	1.0428	2.6903	4.7854

* Significant at 5 % level of significance

Appendix LXIII: Pooled analysis of variance for yield and harvest index of succeeding wheat

Source of variance	d. f.	MSS			
		Yield (kg ha^{-1})			Harvest index (%)
		Grain	Straw	Biological	
YEAR	1	1111706.17	567566.97	90603.63	102.5285
Y X R	4	84984.91	111201.82	189960.06	6.1747
weed mgt. (W)	8	107668.76	56053.47	255744.78	2.5607
W x Y	8	194993.67	166331.95	451591.39	8.6819
Pooled error (a)	32	64583.30	115173.86	137137.02	6.6296
Nutrient mgt.	2	30495.61	102844.82	183932.37	2.3480
F X Y	2	34847.12	81543.06	137552.55	3.0703
W x F	16	182960.10	29680.16	213774.19	7.6368
Y X W X F	16	168244.80	16838.44	221860.07	5.5438
Pooled error (b)	72	75540.23	48914.92	119748.10	4.2794

* Significant at 5 % level of significance

Appendix LXIV
Cost of cultivation and prices used to compute economics of QPM

S. No.	Particular	Unit cost (₹)		Cost ha^{-1} (₹)	
		2015	**2016**	**2015**	**2016**
(A)	**Common cost of cultivation**				
1.	Field preparation by tractor (8 hours)	600 h^{-1}	650 h^{-1}	4800	5200
2.	Layout, bunding and sowing (10 man days)	189 man days^{-1}	189 man days^{-1}	1890	1890
3.	Seed (20 kg ha^{-1})	40 kg^{-1}	50 kg^{-1}	800	1000
4.	Seed treatment with fungicide (bavistin 20 g ha^{-1})	0.5 g^{-1}	0.5 g^{-1}	60	60
5.	Thinning (4 man days)	350	350	1400	1400
6.	Hoeing (10 man days)	189 man days^{-1}	189 man days^{-1}	1890	1890
7.	Fertilizer application (5 man days)	189 man days^{-1}	189 man days^{-1}	945	945
8.	Irrigations (2)	300	300	600	600
9.	Harvesting (10 man days)	189 man days^{-1}	189 man days^{-1}	1890	1890
10.	Threshing with thresher (5 hours)	200 h^{-1}	200 h^{-1}	1000	1000
11.	Winnowing (5 man days)	189 man days^{-1}	189 man days^{-1}	945	945
	Total			**16220**	**16820**
(B)	**Cost of treatments**				
	Weed management				
1.	Weedy check	-	-	-	-
2.	Two hand weedings at 15 and 35 DAS (40 man days)	189 man days^{-1}	189 man days^{-1}	7560	7560
3.	Tembotrione 0.125 kg ha^{-1} at 20 DAS Spray charges (2 man days)	13.4 g^{-1} 189 man days^{-1}	13.4 g^{-1} 189 man days^{-1}	2053	2053
4.	Alachlor 2 kg ha^{-1} as PE *fb* hand weeding at 35 DAS (10 man days) Spray charges (2 man days)	0.5 g^{-1} 189 man days^{-1}	0.5 g^{-1} 189 man days^{-1}	3268	3268
5.	Atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS (10 man days) Spray charges (2 man days)	0.6 g^{-1} 189 man days^{-1}	0.6 g^{-1} 189 man days^{-1}	2568	2568
6.	Tembotrione 0.125 kg ha^{-1} at 20 DAS *fb* hand weeding at 35 DAS (10 man days) Spray charges (2 man days)	13.4 g^{-1} 189 man days^{-1}	13.4 g^{-1} 189 man days^{-1}	3943	3943
7.	Alachlor 2 kg ha^{-1} + atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS (10 man days) Spray charges (2 man days)	0.5 g^{-1} 0.6 g^{-1} 189 man days^{-1}	0.5 g^{-1} 0.6 g^{-1} 189 man days^{-1}	3568	3568
8.	Alachlor 2 kg ha^{-1} as PE *fb* Tembotrione 0.125 kg ha^{-1} at 20 DAS Spray charges (5 man days)	0.5 g^{-1} 13.4 g^{-1} 189 man days^{-1}	0.5 g^{-1} 13.4 g^{-1} 189 man days^{-1}	3053	3053
9.	Atrazine 0.5 kg ha^{-1} as PE *fb* Tembotrione 0.125 kg ha^{-1} at 20 DAS Spray charges (5 man days)	0.6 g^{-1} 13.4 g^{-1} 189 man days^{-1}	0.6 g^{-1} 13.4 g^{-1} 189 man days^{-1}	2920	2920
	Nutrient management				
1.	NPK	Urea 4.64	Urea 4.64	4558	4558

		kg^{-1}, DAP 21.84 kg^{-1}, MOP 14.72 kg^{-1}	kg^{-1}, DAP 21.84 kg^{-1}, MOP 14.72 kg^{-1}		
2.	NPK+Zn	Urea 4.64 kg^{-1}, DAP 21.84 kg^{-1}, MOP 14.72 kg^{-1}, $ZnSO_4$ 45 kg^{-1}	Urea 4.64 kg^{-1}, DAP 21.84 kg^{-1}, MOP 14.72 kg^{-1}, $ZnSO_4$ 45 kg^{-1}	5683	5683
3.	NPKS+Zn	Urea 4.64 kg^{-1}, DAP 21.84 kg^{-1}, MOP 14.72 kg^{-1}, $ZnSO_4$ 45 kg^{-1}, $CaSO_4$ 0.90 kg^{-1}	Urea 4.64 kg^{-1}, DAP 21.84 kg^{-1}, MOP 14.72 kg^{-1}, $ZnSO_4$ 45 kg^{-1}, $CaSO_4$ 0.90 kg^{-1}	5816	5816
(C) Sale price of produce					
1.	Maize grain	16 kg^{-1}	16.50 kg^{-1}		
2.	Maize stover	2.80 kg^{-1}	3.00 kg^{-1}		

Appendix LXV: Economics of treatments

Treatment combinations	Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Gross return (₹ ha^{-1})			Cost of cultivation (₹ ha^{-1})			Net return (₹ ha^{-1})			B:C ratio		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
W_1F_1	2446	2638	2542	4236	4458	4347	50995	56896	53946	20778	21378	21078	30217	35518	32868	1.45	1.66	1.56
W_1F_2	2473	2776	2625	4306	4859	4583	51625	60385	56005	21903	22503	22203	29722	37882	33802	1.36	1.68	1.52
W_1F_3	2643	2792	2717	4903	5253	5078	56010	61826	58918	22036	22636	22336	33974	39190	36582	1.54	1.73	1.64
W_2F_1	4351	4460	4406	6989	7529	7259	89190	96177	92683	28338	28938	28638	60852	67239	64045	2.15	2.32	2.24
W_2F_2	4375	4590	4482	7060	7433	7247	89774	98025	93900	29463	30063	29763	60311	67962	64137	2.05	2.26	2.15
W_2F_3	4532	4690	4611	7674	7429	7551	93999	99665	96832	29596	30196	29896	64403	69469	66936	2.18	2.30	2.24
W_3F_1	3905	3958	3931	6755	7044	6900	81399	86433	83916	22831	23431	23131	58568	63002	60785	2.57	2.69	2.63
W_3F_2	4023	4104	4064	6802	7013	6908	83416	88760	86088	23956	24556	24256	59460	64204	61832	2.48	2.61	2.55
W_3F_3	4074	4188	4131	7417	7032	7225	85955	90193	88074	24089	24689	24389	61866	65504	63685	2.57	2.65	2.61
W_4F_1	4033	4155	4094	6858	7141	6999	83734	89986	86860	24046	24646	24346	59688	65340	62514	2.48	2.65	2.57
W_4F_2	4038	4249	4143	6904	7197	7051	83935	91705	87820	25171	25771	25471	58764	65934	62349	2.33	2.56	2.45
W_4F_3	4315	4286	4301	7525	7170	7347	90103	92236	91170	25304	25904	25604	64799	66332	65566	2.56	2.56	2.56
W_5F_1	4107	4204	4155	6868	7212	7040	84941	91002	87971	23346	23946	23646	61595	67056	64325	2.64	2.80	2.72
W_5F_2	4280	4297	4288	6939	7223	7081	87911	92564	90237	24471	25071	24771	63440	67493	65466	2.59	2.69	2.64
W_5F_3	4417	4436	4426	7548	7183	7366	91811	94738	93275	24604	25204	24904	67207	69534	68371	2.73	2.76	2.75
W_6F_1	3931	3975	3953	6755	7134	6944	81804	86981	84393	24721	25321	25021	57083	61660	59372	2.38	2.44	2.41
W_6F_2	4025	4133	4079	6831	7152	6991	83530	89642	86586	25846	26446	26146	57684	63196	60440	2.23	2.39	2.31
W_6F_3	4316	4223	4269	7438	7147	7292	89882	91118	90500	25979	26579	26279	63903	64539	64221	2.36	2.43	2.39
W_7F_1	4226	4217	4222	6926	6634	6780	87011	89480	88246	24346	24946	24646	62665	64534	63600	2.57	2.59	2.58
W_7F_2	4275	4323	4299	6957	7600	7278	87876	94129	91003	25471	26071	25771	62405	68058	65232	2.45	2.61	2.53
W_7F_3	4399	4451	4425	7595	7614	7605	91649	96287	93968	25604	26204	25904	66045	70083	68064	2.25	2.67	2.46
W_8F_1	4351	4448	4399	7054	7440	7247	89360	95709	92534	23831	24431	24131	65529	71278	68403	2.75	2.92	2.83
W_8F_2	4374	4563	4468	7112	7569	7341	89893	97994	93944	24956	25556	25256	64937	72438	68688	2.60	2.83	2.72
W_8F_3	4637	4609	4623	7739	7776	7757	95861	99374	97617	25089	25689	25389	70772	73685	72228	2.49	2.87	2.68
W_9F_1	3693	4467	4080	7087	7265	7176	78935	95506	87221	23698	24298	23998	55237	71208	63223	2.33	2.93	2.63
W_9F_2	4444	4556	4500	7152	7603	7377	91135	97983	94559	24823	25423	25123	66312	72560	69436	2.67	2.85	2.76
W_9F_3	5260	4677	4968	7776	7874	7825	105928	100789	103359	24956	25556	25256	78972	73233	76103	3.16	2.86	3.01