Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat

THESIS

Submitted to

Jawaharlal Nehru Krishi Vishwa Vidyalaya,

Jabalpur

In partial fulfilment of the requirements for the

Degree of

DOCTOR OF PHILOSOPHY

In

AGRICULTURE

(AGRONOMY)

By

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2019

CERTIFICATE – I

This is to certify that the thesis entitled **"Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat"** submitted in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSAPHY** in **Agriculture (Agronomy)** of **Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur** is a record of the bonafide research work carried out by **Mr. Satish Kumar** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

All the assistance and help received during the course of the investigation has been acknowledged by him.

Place: Jabalpur

Date (**Dr. K. K. Agrawal)**
Chairman of the Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	Dr. A. K. Dwivedi	________________________
Member	Dr. H. L. Sharma	________________________

CERTIFICATE – II

This is to certify that the thesis entitled **"Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat"** submitted by **Mr. Satish Kumar** to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfilment toward the requirements for the degree of Doctor of Philosophy in the subject **Agronomy** of the **Department of Agronomy** has been, after evaluation, approved by the External Examiner and the Student's Advisory Committee after an oral examination on the same.

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(External Examiner)

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Chairman	Dr. K. K. Agrawal	____________________
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Member	Dr. A. K. Dwivedi	____________________
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Declaration and Undertaking by the Candidate

I, **Mr. Satish kumar** S/o Shri Premnarayan certify that the work embodied in thesis entitle **"Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat"** is my own first hand bonafide work carried out by me under the guidance of **Dr. K. K. Agrawal** at Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2016-2019.

The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

I, undertake the complete responsibility that any act of misinterpretation, mistakes and errors of fact are entirely of my own.

I, also abide myself with the decision taken by my advisor for the publication of material extracted from the thesis work and subsequent improvement, on mutually beneficial basis, provided the due credit is given, thereof.

Place: Jabalpur

Date: **Satish Kumar**

(Student)

ACKNOWLEDGEMENT

First of all, I would like to Thanks Almighty God for giving me this opportunity to express my gratitude to all the dedicated people whose support and kind co-operation encouraged me during the course of investigation.

It is a matter of great jubilance and privilege to express my deepest sense of indebtness and reverence to venerable Dr. K. K. Agrawal, Principal Scientist, Department of Agronomy, Chairman of my advisory committee and most efficient, punctual and sagacious personality. I am highly thankful to him for keeping my moral high, being attentive and providing valuable suggestions. It was sure that without his help it would not have been possible to complete this bothersome work of investigation.

I am deeply obliged to all the members of the Advisory Committee *viz.*, Dr. M.L. Kewat, Professor, Department of Agronomy, Dr. Dr. A. K. Dwivedi, Professor and Head, Department of Soil Science and Agricultural Chemistry and Dr. H.L. Sharma, Professor and Head, Department of Mathematics and Agricultural Statistics for their valuable suggestions and help during the course of study.

I feel myself duty bound to express my deep sense of gratitude and thanks to Prof. P.K. Bisen, Hon'ble Vice Chancellor, Dr. D. Khare, Dean Faculty Agriculture, Dr. P. K. Mishra, Director of Research Services, Dr. (Smt.) Om Gupta, Director of Extension Services, Dr. Abhishek Shukla, Director of Instruction, Dr. V.K. Pyasi, Dean Students Welfare, Dr. R.M. Sahu, Dean, College of Agriculture, JNKVV, Jabalpur, for providing me all necessary facilities during the research work.

I extend my sincere gratitude to Dr. V.B. Upadhyay, Professor and Head, Department of Agronomy, Dr. P.B. Sharma, Dr. V.K. Shukla, Dr. A.K. Jha, Dr. J.K. Sharma, Dr. R.P. Sahu, Dr. (Smt) Arti Shrivastava, Dr. (Smt) Nisha Sapre for their kind and able guidance. I express my sincere thanks to all staff members of Department of Agronomy and central library, JNKVV, Jabalpur, for their unfailing co-operation during the course of investigation.

I would like to carry out my overwhelming thanks to my seniors Mr. Suresh Mhaske and my friends Anupama K., Sonal Tolwani, Raj Babar Jatav, Mr. Sharad Sinde, Geeta Arya, Bheru Lal Kumhar, Vijay Uikey and Jitendar Patidar who have inspired me in all respects during this study to which I remain beholden forever.

I have no words to express my gratitude to my father Shri Premnarayan Jatav, mother (Smt.) Ramkali Devi, my wife Manju Baraiya my brother Dileep, Sandeep, Arvind and my loving sister Anjali, Sapna, Rani whose love, blessings, affectionate encouragement, support, constant inspiration and care throughout my life enabled me in my ascent to the present accomplishment.

Place: Jabalpur

Date: **(Satish Kumar)**

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation		Meaning
@	:	At the rate of
et al.	:	And other or co-worker
vs.	:	Against
a.i.	:	Active ingredient
ANOVA	:	Analysis of variance
B :C	:	Benefit :Cost
^{0}C	:	Centigrade
CGR	:	Crop growth rate
CD	:	Critical difference
conc.	:	Concentration
cal. F	:	Calculated f value
df	:	Degree of freedom
DAS	:	Dats after sowing
DAA	:	Days after applcation
etc.	:	Etcetera
Even.	:	Evening
g	:	Gram
GMR	:	Gross monetary return
ha	:	Hectare
hrs	:	Hours
HI	:	Harvest index
Ha	:	Hectare
JNKVV	:	Jawaharlal Nehru Krishi Vishwa Vidyalaya
j.	:	Journal
kg	:	Kilogram
L	:	Litre
LAI	:	Leaf area index
MOP	:	Muriate of potash
MSS	:	Mean sum of squares
Mrl	:	Meter row length
M	:	Meter
m^{-2}	:	Meter square
Min.	:	Minimum
Max.	:	Maximum
Mor.	:	Morning

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation		Meaning
Viz.,	:	Namely
NMR	:	Net monetary return
NPK	:	Nitrogen, Phoshporus, Potassium
NS	:	Non significant
No.	:	Number
O.C.	:	Organic carbon
OD	:	Oil dispersible
Day^{-1}	:	Per day
g^{-1}	:	Per gram
%	:	Percentage
/	:	Per
Q	:	Quintal
RDF	:	Recommanded dose of fertilizer
RGR	:	Relative growth rate
RH	:	Relative humidity
₹	:	Rupees
SMW	:	Standard meteorological week
Sem	:	Standard error of mean
SSP	:	Single super phosphate
Temp.	:	Temperature
T	:	Tonne
Var.	:	Variety
vol.	:	Volume
WG	:	Wettable granuals
Yr	:	Year

INTRODUCTION

Wheat is an important staple food crop and serves as backbone of food security in the country. In India, it is the second most important cereal after rice contributing substantially to the national food security by providing more than 50 per cent of the calories to the people who mainly depend on it. During last four decades, wheat production and productivity has increased almost 6-fold and it alone contributes about one – third of the total food grain production in India. In era of climate change and increasing biotic and abiotic stresses, maintaining yield up to required level is going to be formidable challenge in coming future. The total area under wheat in the world is around 219.61 million ha with a production of 729.1 million tonnes (FAO, 2016). In India wheat is grown in an area of about 29.58 million hectares with the production of 99.70 million tonnes and the productivity of 33.71 q ha^{-1} (Anon., 2018). In Madhya Pradesh, it is grown in 5.56 million ha area with the production of 15.9 million tonnes and share in all India production 15.96 %. The five major wheat growing states of Uttar Pradesh, Punjab, Madhya Pradesh, Haryana and Rajasthan contributed nearly 86.0 per cent to the total production in the country. Punjab has the highest average productivity of 4.7 t ha^{-1} followed by Haryana 4.4 t ha^{-1}, Rajasthan 3.1 t ha^{-1}, Gujarat 3.0 t ha^{-1}, Uttar Pradesh 2.8 t ha^{-1}, Madhya Pradesh 2.6 t ha^{-1} and Bihar 2.2 t ha^{-1}. (Agriculture statistics, 2016).

The productivity of the wheat depends upon several factors like crop establishment techniques, irrigation, weed management, fertilizers management and other cultural practices. Among these factors, the hidden war with crop starts by weeds and it caused up to 90 per cent failure of the crop. Weeds are the major deterrent to the development of suitable crop production. The major weed flora in wheat crop observed that predominant weeds associated with wheat were comprised of *Phalaris minor, Poa annua, Polypogon monspeliensis, Avena ludoviciana, Rumex dentatus, Rumex spinosus, Anagalis arvensis, Convolvulus arvensis, Medicago denticulata, Chenopodium* *album, Vicia sativa, Lathyrus aphaca, Circium arvense, Melilotus alba, and* However, *Phalaris minor, Rumex dentatus and Medicago denticulata* were major concern in irrigated wheat (Singh *et al*., 2015).

Since weed dictate most of the crop production practices and causes enormous losses (37.0 to 57.1 %) due to their interference and hence a serious constraint in sustaining productivity of wheat (Verma *et al.,* 2015, Chand L. and Puniya, 2017). Weeds not only reduce the crop yield, deteriorate the quality of farm produce but also trim down the market value of crop (Hussain *et al*., 2012). They mainly compete with crop for nutrients, moisture, space and solar radiation. Most of the wheat growing area in our country is irrigated, which serve the weeds a suitable habitat. The losses caused by weeds have been estimated to be much higher than those caused by insect- pests and diseases together (Fakkar and Amin, 2012).

The judicious management of weed plays an important role in enhancing wheat productivity. Weeds growing in association with irrigated and heavy fertilized crop decline its yield by 15-40 per cent or even higher besides lowering down the quality of produce by way of weed seed contamination (Yadav *et al*., 2006b). Therefore, weed management is a basic requirement and major component of crop production system (Young *et al.,* 1996). However, weeding has never been a priority due to a variety of reasons. Weeds can be controlled manually which is laborious, time consuming, costly, energy intensive and it is only possible on small scale. Mechanical means are economical but it controls only inter - row weeds, not intra - row weeds. In such situations, herbicides offer most ideal, practically effective and economical means of reducing early weed competition and crop production losses. So, chemical method of controlling weeds is most effective, efficient, up-to-date and time saving (Ashiq *et al*., 2007).

Due to industrialization, labour constraints at peak growth period, small family size and under specific situations where weeds are very difficult to be removed manually, the herbicide use becomes inevitable. The chemical control of weeds in general has been realized to be more cost effective and easy compared to manual weeding (Yadav and Malik, 2005; Garcia-Martin *et al.,* 2007). Herbicides form potent tool to check the mixed flora of weeds in close row crops like wheat where manual or mechanical weeding is difficult and certain grassy weeds evade farmers hoe because of botanical mimicry at early growth stage (Yasin *et al*., 2010).

Regular use of the same herbicide year after year has led to problem of herbicide resistance. The sole dependence on herbicide of single mode of action is also not advisable as it has contributed to shift towards difficult to control weeds and rapid evolution of multiple herbicides resistance, which is a threat to wheat production (Singh, 2007). The herbicide, isoproturon and pendimethalin are being used for the last two decades for weed control in wheat. (Walia *et al*., 1998). Combination of grassy and broad leaf weed herbicides was better than their separate application for weed control in wheat (Cheema and Akhtar, 2005). A number of herbicides are recommended for field crops. Continuous use of herbicides may lead to residue accumulation in the soil, restrict the crop choice in a rotation and pollute the drinking water and environment which ultimately causes health hazards. Ideally, Herbicide should remain active in soil for a period sufficient to provide satisfactory weed control and then it must degrade in to innocuous products before the close of the crop season. The persistence of any herbicides may vary with agro-climatic situations *i.e.* soil type, microbes, soil pH, moisture, temperature, sunlight *etc.* Control of weed in the field by soil-applied herbicide is based upon the premise that the herbicide will move from the treated soil into the targeted pest species. This concept may be used by the synthesizing chemist to evaluate the phytotoxicity of different herbicides. The residue chemist uses this concept to determine the rate at which an herbicide is degraded in soil. A farmer, using crop rotations, needs to know whether the phytotoxic properties of a compound have disappeared before planting a sensitive crop into a previously treated soil.

A new herbicide mixture *i.e*. (Halauxifen - methyl 6.95% + Pyroxsulam 25%) has been launched which reportedly gives excellent control of mixed weed flora in wheat. But information on efficacy of said herbicide mixture is not available for Kymore Plateau and Satpura Hill zone of Madhya Pradesh. Therefore, a comprehensive study on "**Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat**" has been proposed with the following objectives:

1. To assess the associated weed flora in wheat
2. To find out the suitable dose of herbicide mixture for broad spectrum weed control
3. To judge the effect of weed control treatment on growth and yield of wheat
4. To study the residual effect of herbicidal treatments on succeeding crop
5. To work out the economics of treatments

REVIEW OF LITERATURE

In this chapter the available literature on the work related to the research problem chosen is reviewed. Though the review of literature was mainly related to wheat crop, relevant research work on some other cereal crops was also included. This chapter also reviews the work done nationally and internationally in the field of weed management in wheat and their effects on yield. The literature pertaining to the present study was reviewed under following subheadings:

2.1 Associate weed flora

Weed species associating with wheat vary from region to region depending on the variations in agro-ecological conditions, cropping systems, cultivation techniques and crops / varieties grown. The weed flora of wheat was mainly comprised of monocot weed namely *Cyperus iria*, and dicot weeds *viz., Cichorium intybus*, *Anagallis arvensis*, *Chenopodium album*, *Medicago denticulata* and *Medicago trancatula*. But with the introduction of dwarf and high yielding varieties, which are more responsive to irrigation and fertilizers after late seventeen's, changed the weed flora identically in irrigated wheat ecosystem.

Kumar *et al.* (2011) reported that, dominant weeds in the wheat field were *Phalaris minor, Avena ludoviciana, Lolium temulentum, Vicia sativa, Lathyrus aphaca, Stellaria media, Coronopus didymus, Anagallis arvensis, Spergulla arvensis* and *Polygonum alatum* at Palampur, Himachal Pradesh. The other weed species of minor importance were *Poa annua*, *Alopecurus myosuriodes* and *Plantago spp.* at same place.

Hessain (2013) found that, the wheat was infested with mixed population of *Avena fatua, Bromus tectorum, Lolium multiflorum, Medicago* sp*., Brassica tournefortii, Chenopodium album, Anagallis arvensis* and *Convolvulus arvensis* in Libya.

Kumar *et al.* (2013) found that weed flora of the experimental field was mainly composed of grassy weeds as they constituted 88.9 and 91.2% of the total weed flora at 90 DAS and at harvest, respectively. *Phalaris minor* (25.8 and 31%), *Avena ludoviciana* (31.4 and 18.6%), *Lolium temulentum (*14.3 and 22.1%) and *Poa annua* (17.4 and 19.5%) were the important grassy weeds at 90 DAS and at harvest, respectively. *Vicia sativa* (5.5 and 8.8% at 90 DAS and at harvest, respectively) and *Coronopus didymus* (5.5% at 90 DAS) were important broad-leaved weeds. Chander *et al.* (2013) also reported that *Phalaris minor* and *Avena ludoviciana* were the most predominant weeds constituting 66.5 and 27.65% of the total weed flora. The other weeds found growing in association with wheat crop were *Lolium temulentum* (2.0%), *Vicia sativa* (3.0%) and *Coronopus didymus* (0.6%) at same place.

Yadav and Dixit (2014). identified dominant weed species in the wheat field as *Phalaris minor* (66.38%), *Avena ludoviciana*(20.44%), *Cichorium intybus* (11.76%), *Euphorbia geniculata* (0.74%), *Medicago denticulata* (0.32%), *Vicia sativa* (0.20%), *Physalis minima* (0.13%), *Chenopodium album* (0.03%). The relative density of monocot and dicot weeds at 30 days after sowing (DAS) was 86.82 and 13.18 per cent, respectively, indicating the predominance of monocot weeds in wheat.

Jain *et al.* (2014). They found that, irrigated wheat ecosystem was mainly invaded with grassy weeds particularly *Dinebra retroflexa* (31.86 and 29.34%), *Cyperus rotundus* (15.03 and 18.73%) and *Phalaris minor* (9.72 and 7.12%); and dicot weeds *Cichorium intybus* (8.52 and 8.74%) *Medicago hispida* (7.62 and 8.86%), *Alternanthera philoxeroides* (7.41 and 8.61%), *Melilotus indica* (6.41 and 5.87%), *Anagallis arvensis* (5.31 and 4.62%), *Chenopodium album* (4.11 and 4.62%) and *Trifolium fragiferum* (4.01 and 3.50%) during experiment.

Singh *et al*. (2015). observed that predominant weeds associated with wheat were comprised of *Phalaris minor, Poa annua, Polypogonmon speliensis, Avenaludo viciana, Rumex dentatus, Rumex spinosus, Anagalis arvensis, Convolvulus arvensis, Medicago denticulata, Chenopodium album, Vicia sativa, Lathyrus aphaca, Circium arvense, Melilotus alba, and* However, *Phalaris minor, Rumex dentatus and Medicago denticulate* were major concern in irrigated wheat.

Tiwari *et al.* (2015). reported that the wheat crop was infested badly with *Phalaris minor*, *Cyperus rotundus*, *Cynodon dactylon*, *Chenopodium album*, *Anagallis arvensis*, *Avena fatua*, *Convolvulus arvensis* and *Lathyrus aphaca*.

Amare *et al*. (2016). observed that predominant weed flora in wheat comprised of *Avena fatua, Cynodon dactylon, Phalaris minor, Poa annua and Snowdenia polystachia among the grass weeds, and Amaranthus hybridus, Biden pilosa, Chenopodium album, Commelina benghalensis, Commelina arvensis, Datura stramonium, Galinsoga palviflora, Nicandra physelodes, Oxalis latifolia, Polygonum nepalense, and Raphanus raphanistrum* were among broad leaved weeds and *Cyperus esculentus* was the only sedge weed.

Khan *et al.* (2017). Revealed that, common infesting weeds which appeared in wheat field were *Phalaris minor Retz*. and *Cynodon dactylon* (L.) Pers. among grasses, and *Chenopodium album* L., *Anagallis arvensis* L., *Melilotus alba* and *Convolvulus arvensis* L. as broad-leaf weeds. Moreover, among sedges, only one species *Cyperus rotundus* L. was observed.

2.2 Losses due to weed competition

Crop weed competition occurs when the external growth factors are limiting to meet the requirement of both crop and weeds often persist through the major portion of the growing season. The degree of crop weed competition depends upon the type of weed species, duration of weed control, competing ability of crop plants with the weeds and the environmental conditions. Weeds compete with crop for nutrient, moisture, light and space ultimately cause reduction in yield. Some of the grass weeds mimic crop plants for their morphology and growth behavior. Wild oat *(Avena ludoviciana Dur.)* and *Phalaris minor* are of such mimicry weeds in wheat. The acute problem of both grassy weeds along with broad leaf weeds is also common in many parts of the country, which often results in huge yield losses and makes the weed management issue more complex. Weeds growing in association with irrigated and heavy fertilized crop decline its yield besides lowering down the quality of produce (Sharma, 2014).

Khokhar and Nepalia, (2010) found that, uninterrupted weed growth depleted 20.97 kg N, 3.13 kg P and 26.94 kg K ha^{-1}, while it was lowest with isoproturon at 500 g ha^{-1}+ sulfosulfuron at 15 g ha^{-1} Maximum uptake of N (150.20 kg ha^{-1}), P (41.00 kg ha^{-1}) and K (194.14 kg ha^{-1}) by wheat crop was in plots treated with tank mixture of isoproturon at 500 g ha^{-1}+ sulfosulfuron at 15 g ha^{-1}, while in weedy check plots N, P and K uptake by crop was 87.87, 23.82 and 118.04 kg ha^{-1}, respectively.

Hesammi, (2011) found that *Phalaris minor* with 20 to 80 plants per square metre significantly decreased grain weight and grain yield.

Yadav *et al*. (2012) showed that weeds growing throughout the crop season reduced the grain yield of wheat to the extent of 51.6 and 29.5 % during 2008-9 and 2009-10, respectively.

Thus, it may be underlined that weeds compete with crop for nutrients, moisture, solar radiation and space and cause 16-75 per cent reduction in grain yield depending upon the degree of weed infestation, soil condition and agro-climatic conditions of the region.

2.3 Critical period of crop-weed competition

The critical competitive period between crop and weed is the period from sowing up to which the crop has to be kept in weed free situation for realization of maximum profit. The phenomenon of crop life requirements plays an important role in determining the crop yield and under this competition the growth of both weeds and crop plants is affected. The weed and crop compete for common growth factors whose availability is less. At early stage of crop and weeds, leaf area index and root density are low and each plant is able to get its requirement as though every one of them is growing in isolation. In majority of crops, the period of non-interference between crop and weed is very short. Even at low population of weeds also competition is set in at three leaf stage of weeds. In the normal cases the weed competes with the crop mainly for nutrients, water, light, space and carbon dioxide but in some instances weeds show the allelopathic effect on crops.

Cheema and Akhtar (2005) found that, weeds in general, gives competition stress on crop especially during the first 35 DAS and the yield reduced markedly.

Chhokar *et al*. (2008) found that 35 to 45 DAS was critical period for weed control. Weed free condition up to 45 DAS resulted in 67.9% increase in seed yield of wheat over the unweeded control plots. Keeping the wheat weed free for 45 DAS or allowing weeds to remain in the crop for less than 30 days resulted in no significant yield loss.

2.4 Effect of herbicides on weed parameters

Khokhar and Nepalia (2010) showed that, all the herbicidal treatments significantly reduced the dry weight of complex weeds, although they differed in their effect on weed species. While sulfosulfuron and clodinafop alone and as a tank mix with isoproturon effectively controlled grassy weeds than all other herbicide treatments, the tank mix application of isoproturon 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} were equally effective against broad leaf weeds. Minimum weed density, weed dry matter and highest grain yield obtained with isoproturon 500 g ha^{-1} + sulfosulfuron 15 g ha^{-1} followed by isoproturon 500 g ha^{-1} + 2,4-D 500 g ha^{-1} than all other treatments.

Chaudhary *et al*. (2011) reported that, all the herbicides provided good control of narrow and broad leaved weeds and caused significant reduction in their density as compared to control. Pinoxaden + starane - m, puma super + starane - m, atlantis and leader performed better against *Avena fatua L*. with 98.87, 97.10, 96.89 and 91.51 per cent and against *Phalaris minor Retiz* with 98.31, 97.99, 97.67 and 96.95 per cent control, respectively. These herbicides were also provided significant control of all broad leaved weeds.

Singh *et al*. (2011a) revealed that, premix of carfentrazone-ethyl+metsulfuron-methyl (17.5 to 50 g ha^{-1}) with and without surfactant and compared with alone application of carfentrazone - ethyl (20 g ha^{-1}), metsulfuron (4 g ha^{-1}) and 2,4-D amine salt (500 g ha^{-1}) along with weedy check treatment. Premix of carfentrazone+metsulfuron at 25 g ha^{-1}+0.2 % surfactant provided effective control of *Malva parviflora, Lathyrus aphaca, Convolvulus arvensis, Rumex dentatus, Melilotus indica, Medicago denticulata, Anagallis arvensis, Coronopus didymus* and *Chenopodium album* which were not effectively controlled by alone application of these herbicides.

Vazan *et al.* (2011) carried out an experiment to evaluate the efficiency of mesosulfuron-methyl and clodinafop-propargyl against *Lolium perenne* in pure stand and in mixture with wheat. They found that the mesosulfuron-methyl was more potent than clodinafop-propargyl for the control of *L. perenne* as the ED50 values were 0.24 (0.0070) and 0.29 (0.0091) rates for mesosulfuron-methyl and clodinafop-propargyl, respectively. However, no significant difference was found in wheat grain yields with 50% and full rate of application (24 g/ha) of mesosulfuron-methyl.

Malik *et al*. (2012) reported that, different herbicidal treatments, clodinafop 60 g ha^{-1} was effective (95-98 %) only against grassy weeds. Metsulfuron 4 g, carfentrazone 20 g and 2, 4-DE 500 g ha^{-1} reduced the dry weight of broad leaf weeds to the extent of 95-98% but these were not effective against grassy weeds.

Bharat *et al*. (2012) reported that application of tank mixture of sulfosulfuron + 2,4-D was found at par with fenoxaprop + metribuzin, clodinafop + metsulfuron and isoproturon + 2,4-D as well as single application of metribuzin in reducing total weed population and dry weight compared with weedy check. Maximum weed population and dry weed biomass was recorded in weedy check.

Katara *et al*. (2012) revealed that, pinoxaden 50 g ha^{-1} alone and as tank mixture with and before metsulfuron-methyl 4 g ha^{-1}, carfentrazone-ethyl 20 g ha^{-1} and 2,4-D 500 g ha^{-1} was compared to isoproturon + 2,4-D, clodinafop *fb* 2,4-D, weed free and weedy check for weed control and grain yield. *Phalaris minor* and *Anagallis arvensis* were the major weeds constituting 59.1 and 20.8 % of the total weed population during 2010-11 and 67.6 and 16.9 % during 2011-12, respectively. *Avena ludovician*, *Lolium temulentum, Poa annua* and *Vicia sativa* were the other important weeds found in association with wheat. Pinoxaden + metsulfuron-methyl (50 + 4 g ha^{-1}) and pinoxaden fb metsulfuron-methyl (50 fb 4 g ha^{-1}) were comparable to weed free treatment in reducing the density of *Phalaris minor* and *Anagallis arvensis*. Pinoxaden alone was not effective against broad-leaved weeds, while carfentrazone, metsulfuron-methyl and 2,4-D were not effective against grasses. Combined application of pinoxaden with metsulfuron-methyl/carfentrazone (as tank mixed or as followed by) resulted in significantly lower total weed density and weed biomass.

Arora *et al*. (2013) reported that, the maximum weed population and dry weight was recorded in weedy check. However, the application of isoproturon at 1.0 kg ha^{-1} caused maximum reduction in weed density being at par with isoproturon 2.0 kg ha^{-1}, two hand weeding, clodinafop 60 and 120 g ha^{-1} and found significantly superior over sulfosulfuron (25 and 50 g ha^{-1}) and fenoxaprop at (120 and 240 g ha^{-1}) including weedy check. While lowest weed dry weight was recorded in isoproturon 2.0 kg ha^{-1} followed by isoproturon 1.0 kg ha^{-1}, sulfosulfuron 50 g ha^{-1} and sulfosulfuron 25 g ha^{-1}. Dry weight of weeds under all herbicidal treatments and two hand weeding were at par to each other except fenoxaprop at both doses i.e.120 and 240 g ha^{-1} and weedy check.

Singh *et al.* (2015) revealed that, among the herbicidal treatments, post-emergence application (30 DAS) of sulfosulfuron + metsulfuron (32 g ha^{-1}) with higher rates 160 kg N ha^{-1} and time of application (50% basal + 25% CRI + 25% flowering) performed significantly with respect to reduction in density and biomass of weeds

Yadav and Choudhary (2015) reported that, the maximum reduction in weed density and weed dry matter was recorded in the plots treated with metribuzin followed by isoproturon and sulfosulfuron at 45 DAS and at harvest.

Nanher *et al*. (2015) found that, significantly reduced the weed population, dry weight of weed ,highest weed control efficiency and minimum loss of nutrient were recorded with the application of sulfosulfuron .+ metribuzin 25 + 105 g *a.i*. ha^{-1} as post - emergence established its superiority over rest of the herbicides**.**

Chhokar *et al.* (2015) reported that efficacy of halauxifen-methyl ester in combination with florasulam 12.76 (6.51+6.25) g ha^{-1} was poor against *Solanum nigrum* and *Physallis minima*, *Rumex dentatus*, whereas, halauxifen+florasulam 12.76 g ha^{-1}, metsulfuron 4 g ha^{-1} and metsulfuron+ carfentrazone 4+20 g ha^{-1} gave excellent control.

Negi and Chopra (2015) reported that, all herbicidal treatments resulted in significant reduction of count and dry matter of total weeds.

Sharma *et al*. (2015) reported that the Tank mix application of clodinafop + metsulfuron methyl 60+4 g ha^{-1} being at par with clodinafop 60 and120 g ha^{-1} resulted in recording significantly lower weed count and weed dry matter of total weeds.

Pal *et al*. (2016) reported that the efficacy of different herbicides on weed population, productivity and nutrients acquisition of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.]. Among the herbicidal treatments, readymix applications of mesosulfuron + iodosulfuron (24 + 4.8 g ha^{-1}) recorded the lowest weed density and NPK removal by weeds.

Sudha *et al.* (2016) found that, the lower weed density, weed biomass and higher weed control efficiency was recorded with sulfosulfuron + metsulfuron 25 + 4 g ha^{-1} followed by clodinafop + metsulfuron 60 + 4 g ha^{-1} compared to weedy check.

Choudhary *et al.* (2016) revealed that, minimum weed density per m^2 and weed dry weight (5.13 and 17.31 g) was recorded with sulfosulfuron at 25 g ha^{-1} followed by clodinofop at 60 g + metsulfuron methyl at 4g ha^{-1} (5.19 and 18.45 g), metribuzin at 200 g ha^{-1} (5.85 and 25.98 g), pendimethalin at 1000 g *fb* 2,4-D at 400 g ha^{-1} (6.49 and 31.73 g) and hand weeding twice (7.01 and 35 g), respectively. Also, maximum weed control efficiency was recorded under sulfosulfuron at 25 g ha^{-1} (83.85 %) followed by clodinofop at 60g + metsulfuron methyl at 4 g ha^{-1} (83.17 %) and metribuzin at 200 g ha^{-1} (75.85 %), respectively.

Ghosh *et al.* (2017) revealed that, pre and post-emergence herbicides applied in sequence proved more effective in reducing population and total dry matter of weeds and recording higher weed-control efficiency as compared to their sole application.

Kumar *et al*. (2018) reported that, the different herbicides ready mix application of sulfosulfuron + metsulfuron (32 g ha^{-1}) significantly reduced weed density and dry biomass accumulation, and which was followed by application of mesosulfuron + iodosulfuron and mertibuzin over weedy check.

Ziar *et al.* (2017) revealed that, sulfosulfuron 25 g ha^{-1} at 35 DAS resulted in significant reduction in weed growth (population and dry weight) and caused a considerable increase in weed control efficiency (WCE) and weed control index (WCI) in wheat.

Sahu *et al.* (2018) post - emergence application of sulfosulfuron 75 % WG (25 g ha^{-1}) + metsulfuron-methyl 20% WP (2 g ha^{-1}) at 30 days after sowing (DAS) was very effective against broad leaf weeds and annual grasses, and recorded significantly lower density and biomass of these weeds at 60 DAS as compared to isoproturon 75% WP 1.0 kg ha^{-1}.

Devi *et al*. (2018) reported that tank mix application of pinoxaden (50 g ha^{-1}) + RM of carfentrazone and metsulfuron (25 g ha^{-1}) recorded lowest total weed density, weed index and weed persistence index, and highest value of weed control index over other herbicidal treatments.

Singh *et al*. (2018) revealed that, dominant weed species *i.e. Phalaris minor*, *Rumex dentatus* (L.), *Meliotus indica* (L.), *Chenopodium album* (L.) *and Launaea nudicaulis* (L.). Minimum weed density per m^2, weed dry weight (4.17 and 1.57 q ha^{-1}) and NPK uptake (1.77, 0.23 and 2.73 kg ha^{-1}) was found under hand weeding 30 DAS over weedy check.

2.5 Influence of herbicides on growth & yield attributes of wheat

Ahmed and Tarique (2010) reported that the highest plant height (cm), plant weight (g), number of total tillers per plant, number of fertile tillers per plant, panicle length (cm), number of spikelets per spike, number of florets per spikelet, 1000 grain weight (g), straw yield (t ha^{-1}) and grain yield (t ha^{-1}) were observed in weed free treatment. The next highest yield and other yield contributing characters were recorded in 2,4-D treatment.

Brar and Walia (2010) reported that, the application of clodinafop 60 g ha^{-1}, sulfosulfuron 25 g ha^{-1} and mesosulfuron + idosulfuron 14.4 g ha^{-1}, recorded significantly higher wheat growth parameters, yield attributes, grain and biological yield as compared to unweeded control treatment.

Walia *et al*. (2010) found that maximum grain yield was recorded with the post emergence application of sulfosulfuron + metsulfuron at 30 g ha^{-1} which was statistically at par with all herbicidal treatments.

Chhokar *et al*. (2011) reported that grass was significantly poor, when sulfosulfuron or its ready mix combination with carfentrazone was applied without surfactant compared with surfactant.

Meena and Singh (2011) reported that, the herbicidal weed control had significantly higher grain yield in comparison to weedy check. sulfosulfuron 30 g ha^{-1} + metsulfuron methyl 2 g ha^{-1} had higher grain yield than alone application of 2, 4-D @ 625 g ha^{-1} and metsulfuron methyl 4 g ha^{-1}.

Sharma and Singh (2011) observed that, mechanical weeding twice at 15 and 30 DAS proved the most effective treatment in reducing weeds dry weight which was at par with sulfosulfuron 25 g ha^{-1} and gave significantly higher grain yield and NPK uptake by wheat than weedy check. Mechanical weeding at 15 and 30 DAS registered the highest (35.4 - 45.1 %) is increasing in grain yield over weedy check, but highest net returns (27,620 – 32,224 ha^{-1}) and benefit : cost ratio (1.79 – 1.89) were obtained with sulfosulfuron (25 g ha^{-1}).

Singh *et al*. (2011b) observed that premix of carfentrazone + metsulfuron 25 g ha^{-1} with 0.2 % NIS increased tiller numbers by 26 %, biological yield by 28 % and grain yield of wheat by 31 % over untreated control. Crop injury (5-15 %) by the application of carfentrazone + metsulfuron with 0.2 % NIS or carfentrazone alone was transient and caused no reduction in crop yield. In another field study, metsulfuron, carfentrazone and their tank mix produced 41 % higher tillers of wheat over untreated check.

Saqib *et al.* (2012) reported that, the statistically higher grain and straw yields (4.03 and 5.35 t ha^{-1}, respectively) were recorded under weed free plots than rest of the treatments due to superior values of the yield attributes of wheat *viz.,* panicle length (8.16 cm), number of spikelets per panicle (17.36), grain weight per plant (8.33 g). However, among the herbicide treatments, post - emergence application of sulfosulfuron at 25 g ha^{-1} recorded statistically higher grain and straw yields (3.71 and 4.78 t ha^{-1}, respectively) being at par with hand weeding once at 30 DAS and application of metribuzin 175 g ha^{-1} over other herbicidal treatments including weedy check.

Kumar *et al.* (2013) recorded higher plant height, higher numbers of spiklets per spike, effective tillers and grain yield with application of clodinafop 60 g ha^{-1} than application of sulfosulfuron 25 g ha^{-1}.

Punia *et al.* (2013) reported that, sulfosulfuron + metsulfuron produced effective tillers and grain yield of wheat statically at par with weed-free check, which was 40-42% higher than weedy check.

Malekian *et al*. (2013) observed that the most effective herbicide treatment was metsulfuron - methyl plus sulfosulfuron at 36 and 32 g *a.i.* ha^{-1} which provided maximum reduction in total weedy dry matter by 98.6 % and 97.55 % in two years of trial. All herbicide treatments increased wheat biological and grain yield as compared with the weedy check. Maximum grain yield among herbicide treatments was observed with metsulfuron - methyl plus sulfosulfuron at 36 g *a.i*. ha^{-1}.

Yadav and Dixit (2014) reported that application of clodinafop 60 g ha^{-1} + 2,4-D 500 g ha^{-1} had higher number of spikes, number of effective tillers and grain yield of wheat followed by alone application of 2,4-D but both were superior over alone application of sulfosulfuron at 25 g ha^{-1} and weedy check.

Nabiha *et al.* (2014) also reported that, total chlorophyll including chlorophyll a and chlorophyll b, decreased with increased chevalier (mesosulfuron methyl + iodosulfuron methyl - sodium) herbicide concentrations (0.6, 0.9, 1.2 and 1.5 mg $plot^{-1}$) in wheat leaves.

Study of Kaur and Brar (2014) revealed that, higher dose of mesosulfuron + iodosulfuron (18 g ha^{-1}) had in significant less plant height than its lower dose (12 g ha^{-1}) at harvest due to toxic effect of herbicide. However, increase in grain yield was 11.2, 14.6, 11.0 and 4.45 % was achieved with the application of sulfosulfuron at 25 and 37.5 g ha^{-1} and mesosulfuron + iodosulfuron at 12 and 18 g ha^{-1} over unsprayed control, respectively. Results also indicated the toxic effect of higher dose of mesosulfuron + iodosulfuron (18 g ha^{-1}) as grain yield was reduced from 15.8 to 15.6 t $ha^{-1}$and 16.1 to 14.4 t ha^{-1} with the increase in dose of mesosulfuron + iodosulfuron from 12 to 18 g ha^{-1} during 2003-04 and 2004-05, respectively. However, the straw yield was similar during first year but there was some reduction (42.5 to 39.4 t ha^{-1}) during second year.

Sharma *et al*. (2015) reported that, clodinafop applied at either 60 or 120 g ha^{-1} being at par with both combinations of herbicides *i.e.* clodinafop + metsulfuron - methyl 60 + 4 g ha^{-1} and isoproturon+ 2,4-D 1.0 + 0.5 kg ha^{-1} produced significantly higher grain, straw and biological yield of wheat.

Soltani and Saeedipour (2015) found that, the highest number of spike was in weed treatment which had not significant difference compared to metsulfuron-methyl plus sulfosulfuron (total) at all levels of nitrogen except zero level. The lowest spike number was recorded in the weedy check at the highest level of nitrogen and also observed that all herbicide treatments improved wheat biological yields compared to the weedy check. However, metsulfuron-methyl plus sulfosulfuron consistently provided the highest biological yield. Minimum biological yield was achieved with topik + granstar herbicide.

Pal *et al*. (2016) reported that, efficacy of different herbicides on weed population, productivity and nutrients acquisition of wheat. Application of sulfosulfuron and metsulfuron (20 + 4 g ha^{-1}) recorded the maximum values of plant height (89.81 cm at harvesting), number of tillers m^{-2} (93.39 at harvest), grain yield (5.23 t ha^{-1}) and nutrients uptake (142.4 kg N, 18.90 kg P and 117.23 kg K ha^{-1}), which was closely followed by weed-free, mesosulfuron + iodosulfuron (24 + 4.8 g ha^{-1}), (18 + 3.6 g ha^{-1}) and tank-mix clodinafop + metsulfuron (60 + 4 g ha^{-1}).

JNKVV, (2017) clodinofop + metsulfuron- (60+4 g *a.i.* ha^{-1}) recorded highest grain yield of wheat which was significantly at par with phenoxaprop + metribuzin (120 + 210 g *a.i.* ha^{-1}), sulfosulfuron + metribuzin (32 g *a.i* ha^{-1}) and mesosulfuron + iodosulfuron (14.4 g *a.i.* ha^{-1}) over the control.

Kaur *et al.* (2017) revealed that, application of pendimethalin and metribuzin provided control of *Rumex dentatus* to the extent of 98-100 % and 68-92 %, respectively, while provided 98-100 and 63-72 %, respectively control of *C. album*. Sequential application of pendimethalin as pre-emergence followed by sulfosulfuron as post-emergence recorded the highest weed control efficiency (96 %) and wheat grain yield (4.8 t ha^{-1})

2.6 Weed control methods

2.6.1. Hand weeding

Meena and Singh, (2011) reported increased seed yield by 86.47 and 80.04 % with 2 hand weeding over the weedy check was observed mainly owing to manual removal of associated weed flora.

Sasode *et al.* (2017) revealed that, the highest mortality of weeds and the maximum grain yield of 5.00 t ha^{-1} and 4.07 t ha^{-1} with 38.2 %, 31.0 % increase in grain yield over weedy check were recorded with two hand weeding at 30 and 60 DAS (weed free).

Barla *et al.* (2017) found that, two hand weeding performed in wheat crop at 30 and 60 DAS recorded significantly reduced weed density and weed dry matter of broad-leaf, grassy, sedges and total weeds at 30 and 60 DAS with WCE of 94.3 and 94.2 %, respectively and was similar to post - emergence application of clodinafop 0.06 kg ha^{-1} and pre - emergence application of pendimethalin + metribuzin 1.0 kg ha^{-1} + 0.175 kg ha^{-1}.

2.6.2. Chemical weed control

Due to scarcity of farm labour during critical period of weeding, the intercultural operations are partially beneficial. Moreover, lack of abundance of soil moisture makes the hand weeding and intercultural operations impossible. These drawbacks of mechanical method of weed control resulted in inadequate control of weeds and low yield of the crops. Thus, chemical method of weed control is the most promising way of weed control when followed with proper time lines and precision. It is more efficient, economical, kills the target plants without any phytotoxic effect on the crop, eliminates early crop weed competition and results good harvest of the crop. The progress in herbicide technology has paved the way for the development of new post emergence herbicides in wheat. At present several herbicides are available for weed control in wheat, out of which Isoproturon was most widely used. New herbicide *viz*., halauxifen-methyl, pyroxsulam sulfosulfuron and fenoxaprop. pyroxasulfone came into existence and competing well with isoproturon. As the wheat fields are generally infested with both grassy as well broad-leaved weeds, there is urgent need to judge the relative efficacy of these herbicides along and in combination with other herbicides for broad-spectrum weed control. The available research work on post emergence herbicides in wheat has been reviewed critically and being presented as under.

Malik *et al.* (2008) reported that, application of metsulfuron in wheat at various doses (3, 4 and 5 g ha^{-1}) against broadleaf weed in wheat. metsulfuronat 4 g ha^{-1} was better than its application at 3 g ha^{-1}.

Yadav and Dixit (2014) also reported that alone application of sulfosulfuron 25 g ha^{-1} was superior against both grassy and BLW, whereas, alone application of clodinafop 60 g ha^{-1} was more superior against grassy weeds than tank mixture of clodinafop+ 2,4-D in wheat.

Singh *et al*. (2015) found that, application of atlantis 400 g ha^{-1} registered higher dry weight of grassy weeds (40.8 g ha^{-1}) recorded highest WCE (83.36 %) as compared to alone application of clodinafop and sulfosulfuron. However, alone application of clodinafop 60 g ha^{-1} was more effective in controlling grassy weeds as it had 4.5 g m^{-2} dry weight than atlantis (40.8 g m^{-2}) and sulfosulfuron (29.9 g m^{-2}). Whereas, alone application of sulfosulfuron was superior to clodinafop but inferior to atlantis against BLW in wheat.

Chaudhari *et al.* (2017) found that, application of herbicides significantly reduced the density and biomass of both monocot as well as dicot weeds and resulted in significantly more number of effective tillers and yield of grain and straw.

Rana *et al*. (2017) revealed that, application of clodinafop + metsulfuron resulted in highest weed control efficiency (WCE), weed control index (WCI), crop resistance index (CRI), treatment efficiency index, crop intensity index and weed index. Weed management index, agronomic management index and integrated weed management index were highest under sulfosulfuron followed by clodinafop + metsulfuron.

Stanzen *et al.* (2017) showed that, post-emergence application of metribuzin at 200 g ha^{-1} resulted in lowest total weed density and biomass of weeds, which was statistically at par with two hands weeding and significantly lower than weedy check. The post - emergence application of metribuzin at 200 g ha^{-1} also recorded highest weed control efficiency (WCE).

Punia *et al.* (2017) revealed that, mixtures and sequential application for the control of the resistant *Phalaris minor* and other weeds in wheat. mesosulfuron + iodosulfuron 14.4 g ha^{-1} provided better control (85-90 %). pinoxaden 50 g ha^{-1} resulted in 80 per cent control of *P. minor* during first year but it provided only 55 per cent control during second year. Ready - mix combination of metribuzin with fenoxaprop and clodinafop significantly improved the control of *P. minor* and broad leaf weeds as compared to alone application of Fenoxaprop and Clodinafop.

Singh *et al.* (2017) found that, emergence of weeds from upper soil surface was effectively controlled by herbicides.

Baghel *et al.* (2018) reported that, the sequential applications of pendimethalin @ 1.5 kg ha^{-1} as pre-emergence, and bispyribac-Na @ 25 g ha^{-1} at 25 days after sowing (DAS) as post emergence resulted in better control of weeds and higher weed-control efficiency (WCE).

Chopra and Saini (2018) revealed that, the highest weed control efficiency (87.8%) and benefit : cost ratio (1.59) were found under culfosulfuron + metsulfuron 75 WG @ 0.03 kg ha^{-1} treated plots, closely followed by sulfosulfuron 75 WG @ 0.02 kg ha^{-1} and mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g ha^{-1}.

Kaur *et al*., (2018) revealed that, pendimethalin 2.5 l ha^{-1} + atlantis 400 g ha^{-1} was found effective to control weed population and produced higher number of grains per ear and enhanced grain yield up to 62.3 per cent over weedy check.

2.7 Economics of different weed management practices in wheat

Ali *et al.* (2003) reported that, chemical weed control had higher cost - benefit ratio (1:2.88) and revenue per crop per day (Rs. 77) as compared to hand weeding.

Jain *et al*. (2007) revealed that, application of clodinafop-p-propargyl followed by 2, 4-D attained higher B:C ratio (2.61) than isoproturon + 2, 4-D (1.66), being the minimum (1.25) under the weedy check plots where weeds were allowed to grow throughout the growing season in case of wheat crop.

Chaudhry *et al*. (2008) assessed the efficacy and economics of herbicidal mixtures against narrow and broad leaved weeds in wheat crop and found that isoproturon (2.00 kg ha^{-1}) + buctril super (750 and 560 ml ha^{-1}) gave higher net returns (Rs. 16544 and 15066 ha^{-1}) with benefit cost ratio of 9.73 and 9.40, respectively.

Saini and Walia (2010) reported that, all the weed control treatments have higher net returns when compared with unweeded control. On an average, mesosulfuron + iodosulfuron, sulfosulfuron and pinoxaden treatments gave additional net profit of Rs. 22,680, 22180 and 21,520 ha^{-1}, respectively when compared with control treatment.

Khaliq *et al.* (2011) found that, reduced doses of iodosulfuron + mesosulfuron were quite effective in suppressing total weed density (72- 95 %) and biomass (83-94 %). The maximum marginal rate of return was recorded for 50 % of the label herbicide dose (7.2 g ha^{-1} of iodosulfuron + mesosulfuron), followed by 25% of the label dose (3.6 g ha^{-1}).

Sharma *et al*. (2015) reported that, the tank mix application of clodinafop + metsulfuron - methyl 60+4 gha^{-1} in wheat. clodinafop 60 g ha^{-1} was the best in recording highest net returns of Rs. 29385 ha^{-1}

with B : C ratio of 1.21, followed by clodinafop + metsulfuron methyl 60 + 4 g ha^{-1} and isoproturon+2, 4-D 1.0+0.5 kg ha^{-1} having net returns of Rs. 29364 and 28386 ha^{-1}, respectively, with similar B : C ratio of 1.19.

Sasode, *et al.* (2017) revealed that, highest B:C ratio of (3.69) was obtained with pinoxaden + metsulfuron (pre-mix) followed by sulfosulfuron + metsulfuron (3.67).

2.8 Phytotoxicity effect of herbicides on succeeding crop

Ideally, an herbicide should remain biologically active long enough to provide satisfactory weed control at least up to critical period of crop-weed competition and after that period, must degrade into non-toxic components both in soil and plant biomass. Studies on residual effect of any herbicides are important before it is finally recommended for field applications to the farmers. The residual effect of herbicides depend on soil texture, soil reaction, organic matter content and climatic conditions of a place. Herbicides with higher residual effect may causes phytotoxicity to the succeeding crop in the rotation. Whereas, an ideal herbicide not only controls the weeds in the crop in which it is applied but also in the succeeding crop without phytotoxicity to the crop in the rotation.

Kewat *et al*. (2000) reported that, application of metribuzin as pre – emergence in soybean appreciably lowered the weed population and biomass. Also, about 50 per cent of the metribuzin was lost within 45 days, thus, no residual effect was detected in succeeding crop.

Sharma *et al*. (2002) found residual effect of chlorsulfuron on growth and quality of succeeding forage sorghum crop, when, applied in wheat at 30 g ha^{-1}. Application of pinoxaden at 40 g ha^{-1} significantly reduced weed count and biomass in wheat crop and observations on weed control and yield were comparable with untreated one, sowing no residual effect of this chemical on the succeeding crop.

Kaur *et al.* (2004) studied that, little seed canary grass (*Phalaris minor* Retz.) is a major weed in wheat fields and has developed resistance to the commonly used herbicide isoproturon. This study explores the potential use of isoxaflutole a pre-emergence herbicide to control little seed canary grass. Green house studies were carried out to determine the phytotoxicity of isoxaflutole in relation to shoot height, fresh shoot biomass and leaf chlorophyll concentration of wheat and little seed canary grass. Results indicate that isoxaflutole 0.5 mg/L significantly reduced the shoot height of little seed canary grass but no significant reduction in the shoot height of wheat was observed when compared to control.

Geminiani *et al*. (2006) studied that, experiment conducted in Italy to investigate the sensitivity of the Neodur Duilio Meridiano Levante Orobel and Vetrodur cultivars of winter wheat towards post-emergence applications of herbicides iodosulfuron methyl-sodium + fenoxaprop-p-ethyl + mefenpyr-diethyl mesosulfuron-methyl + iodosulfuron-methyl-sodium + mefenpyrdiethyl clodinafop-propargyl + cloquintocet-mexyl mixed with tribenuron-methyl and clodinafop-propargyl + cloquintocet-mexyl mixed with tribenuron-methyl and carfentrazone-ethyl. The results showed that all the tested herbicide mixtures were well tolerated by the wheat cultivars. Phytotoxicity occurred occasionally but no yield reductions were recorded.

Cogliatti *et al.* (2011) reported that, there are currently no herbicides registered in Argentina for the selective control of grassy weeds in annual canarygrass (*Phalaris canariensis* L.). The principal grassy weeds are darnel ryegrass (*Lolium temulentum* L.) and wild oats (Avena fatua L.), which cause grain yield and quality losses. The potential of diclofop-methyl and clodinafop-propargyl for their control was assessed through green house and field trials, in which crop phytotoxicity and weed control efficacy were evaluated. It was found that field application of clordinafop-propargyl resulted in severe crop damage, except for low doses that did not affect the species to be controlled.

Thus, it can be concluded that application of herbicides in a crop, not only control the weeds throughout the crop period but sometimes take care of weeds in succeeding crops. It is due to their residual effect.

However, most of herbicides applied in wheat have least residual properties and degrading in soil within crop period, thus produce no adverse effect on succeeding crops except few at higher doses.

MATERIALS AND METHODS

An experiment was conducted to study the "**Evaluation of Halauxifen-methyl 6.95% + Pyroxsulam 25% efficacy against weed flora in wheat**" during both the years 2016-17 and 2017-18 of *Rabi* season under agro-climatic conditions of Jabalpur (M.P.). The materials used and the methods employed during the course of investigation in the field as well as laboratories are briefly described in this chapter under the appropriate heads. The edaphic and weather conditions in the locality also exert their marked influence on growth development and yield of the crops. Hence, these parameters are also elucidated here in brief.

3.1 Experimental site

A field experiment was conducted at Research Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP.). The field selected for experimentation was fairly infested with location specific weeds representing to this area. All physical facilities *viz.*, labours, agro - chemicals, equipments and irrigation water etc. were adequately available at the Research farm.

3.2 Climate

Jabalpur is situated at 23°09' North latitude and 79°58' East longitude with an altitude of 411.78 meters above the mean sea level. The climate of the locality is characterized as typically sub-tropical and sub- humid, which is featured by hot dry summer and cool dry winters. It has been classified as "Kymore Plateau and Satpura Hill" agro climatic zone as per norms of National Agricultural Research Project, Indian Council of Agricultural Research (ICAR), New Delhi. Recently, it has been identified as Agro Ecological region number 10 named as Central High Lands (Malwa and Bundhelkhand), sub-region number 10.1 named as hot-sub humid eco-region (Malwa plateau, Vindhyan scarp land and Narmada valley). The annual rainfall of Jabalpur ranges between 1000 to 1500 mm. Most of rains mainly received between mid-June to end of September with little and occasional rainfall in the remaining part of years. The minimum temperature goes down to 4°C during December and January months, while the maximum temperature reaches as high as 44°C during the months May and June. Generally humidity of the locality remains very low (15 to 30%) during summer season, moderate (60 to 75%) during winter and it attains high value (80 to 95%) during rainy season.

3.2.1 Weather conditions during crop growth

Seasonal variations prevailing during the growing period plays an important role in the developmental process, which may have great influence on the final yield of the crop. The weekly meteorological data were recorded during crop season of Meteorological Observatory College of Agricultural Engineering, JNKVV, Jabalpur and presented in Table 3.1 and are depicted through Figure 3.1.

It is obvious from the meteorological data that the weather conditions which prevailed during the crop season (*Rabi* 2016-17) were favorable for the growth and development of wheat. The mean weekly maximum temperature ranges from (21.7 to 41.6 °C) whereas, mean weekly minimum temperature ranged between 5.5 to 21.6 °C. Whereas, relative humidity varied from 39.0 to 93.0 % in morning and 9.0 to 48.0 % in evening. The mean sunshine hours varied between 6.4 to 10.3 hours per day. Total winter rainfall of 19.4 mm was received.

During the year 2017-18 the mean weekly maximum temperature ranges from 24.7 to 39.3 °C, whereas mean weekly minimum temperature ranged between 3.9 to 20.6 °C. Whereas, relative humidity varied from 53.3 to 88.3 % in morning and 18.0 to 35.0 % in evening. The mean sunshine hours varied between 4.2 to 9.8 hours per day. Total winter rainfall of 51.8 mm was received.

Table 3.1. Weekly meteorological data during crop (*Rabi)* seasons of 2016-17 and 2017-18.

SMW	Temperature (^{0}C)				Relative humidity (%)				Rainfall (mm)		No. of rainy days		Sunshine hours	
	Maximum		Minimum		Morning		Evening							
	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18
44	29.7	31.1	12.3	12.2	91.0	86.0	24.0	27	0.0	0.0	0.0	0.0	8.1	8.8
45	29.7	30.0	10.6	10.2	88.0	87.0	24.0	42	0.0	0.0	0.0	0.0	8.1	7.2
46	28.3	28.9	8.1	11.9	87.0	86.0	22.0	31	0.0	0.0	0.0	0.0	8.3	5.9
47	28.8	27.6	8.4	10.1	89.0	82.0	27.0	21	0.0	0.0	0.0	0.0	8.7	8.6
48	28.8	28.1	8.7	5.1	93.0	80.0	43.0	30	0.0	0.0	0.0	0.0	6.2	6.7
49	25.1	26.7	7.9	8.1	91.0	88.0	28.0	35	0.0	0.0	0.0	0.0	7.8	6.6
50	26.1	27.5	7.3	9.0	91.0	88.0	30.0	32	0.0	0.0	0.0	0.0	7.4	4.2
51	24.7	24.8	5.5	5.5	88.0	86.0	29.0	28	0.0	0.0	0.0	0.0	8.6	7.3
52	25.7	25.2	5.6	3.9	91.0	86.0	24.0	27	0.0	0.0	0.0	0.0	8.1	8.8
1	23.9	28.8	9.1	9.7	90.0	86.6	48.0	29.6	0.0	0.0	0.0	0.0	6.5	7.8
2	21.7	24.7	6.6	12.6	86.0	88.3	42.0	29.3	0.2	0.0	0.0	0.0	7.2	9.1
3	24.1	28.4	9.2	10.5	89.0	87.6	47.0	30.0	0.0	0.0	0.0	0.0	6.4	9.3
4	25.7	31.0	10.1	12.7	97.0	86.1	45.0	24.7	3.2	0.0	1.0	0.0	6.5	9.2
5	25.4	26.7	7.5	6.8	92.0	85.3	38.0	28.0	0.0	0.0	0.0	0.0	9.6	9.8
6	27.2	26.6	9.8	12.4	84.0	81.0	42.0	51.9	0.0	0.0	0.0	0.0	9.0	5.4
7	26.4	25.2	10.6	11.5	95.0	91.3	42.0	44.9	13.2	18.0	1.0	3.0	8.4	6.4
8	29.7	31.2	10.0	12.5	83.0	80.3	26.0	28.4	0.0	0.0	0.0	0.0	10.3	9.8
9	31.2	32.4	11.1	14.0	80.0	79.0	26.0	26.1	0.0	15.0	0.0	1.0	10.2	8.9
10	30.3	30.9	12.5	14.1	72.0	75.0	24.0	32.9	0.0	1.0	0.0	0.0	9.6	6.9
11	29.3	33.3	9.8	15.4	74.0	74.4	16.0	29.6	0.0	0.8	0.0	0.0	10.1	7.4
12	33.9	34.4	14.4	14.7	75.0	63.7	19.0	20.1	2.8	17.0	1.0	1.0	10.0	8.4
13	38.6	37.0	15.9	13.5	69.0	53.9	15.0	18.0	0.0	0.0	0.0	0.0	10.3	9.0
14	39.3	38.0	20.6	18.1	41.0	55.9	15.0	22.0	0.0	0.0	0.0	0.0	10.0	7.5
15	38.1	37.0	14.4	20.6	54.0	67.4	9.0	40.1	0.0	0.0	0.0	0.0	10.2	7.4
16	41.6	39.3	21.6	20.3	39.0	53.3	11.0	18.4	0.0	0.0	0.0	0.0	10.1	9.4
	Average								Total					
	29.33	30.19	10.70	11.82	81.16	79.124	28.64	29.88	19.4	51.8	3.0	5.0	215.7	195.8

Source: Meteorological Observatory, Department of Physics and Agro-meteorology, CoAE, JNKVV. Jabalpur

3.3 Soil

The soil of the Jabalpur region is broadly classified as vertisol as per norms of United State (US) classification of soil. It has medium to deep depth and black in colour. It has ability to swell after wetting and to shrink after drying. Thus, it develops deep and wide cracks on the surface during summer season. It has poor work ability under excessive dry as well as wet condition. The soil of the experimental field offers infestation of several weeds depending on the seasons, crops grown and management practices followed.

In order to know the physico-chemical properties of soil of the experimental field, ten samples were collected randomly from 0-15 cm depth with the help of soil auger prior to start of the field experiment. These soil samples were thoroughly mixed to get the composite sample. After proper drying, the composite sample was powdered finally with the help of mortar and pestle. Requisite quantity of the soil from the composite sample was drawn and then subjected to various analysis as per standard methods adopted in the laboratory at Department of Agronomy, College of Agriculture, JNKVV, Jabalpur.

It is obvious from the soil analysis data (Table 3.2) that the soil of the experimental field was clayey in texture. It was medium in organic carbon (0.54%), available nitrogen (260.12 kg N ha^{-1}), phosphorus (12.25 kg P_20_5 ha^{-1}) and available potassium (295.10 kg K_20 ha^{-1}). The soil was nearly neutral in reaction (7.20 pH) and concentration of soluble salts (0.29 dS m^{-1}) was below to the harmful limit.

Table 3.2. Physico-chemical properties of the soil of experiment field (initial status)

Constituents	Value	Class /group	Method used
A. Mechanical composition			
Sand (%)	25.18	Sandy clay Loam	International pipette method (Piper, 1967)
Silt (%)	19.18		
Clay (%)	55.64		
Organic carbon (%)	0.54	Medium	Walkley and Black rapid titration method (Walkey & Black,1934)
Available nitrogen (kg ha^{-1})	260.12	Medium	Alkaline permanganate method (Subbiah & Asija,1956)
Available P2O5 (kg ha^{-1})	12.25	Medium	Calorimeter method (Olsen *et al.,* 1954)
Available K2O (kg ha^{-1})	295.10	Medium	Flame photometer method (Jackson, 1967)
Soil pH (1:2.5 soil water ratio)	7.2	Neutral	Glass electric pH meter (Piper,1967)
Electrical conductivity (dSm^{-1})	0.29	Low	Solu-bridge method (Black, 1965)

3.4 Cropping history of the Field

It is obvious from the information given in the Table 3.3 that soybean - wheat cropping system was followed in the experimental field with the uniform dose of fertilizers. It means the fertility status of the soil in the field was almost homogeneous. However, present experiment was taken in two *Rabi* seasons of 2016-17 and 2017-18.

Table 3.3. The Cropping history of the experimental field during past five years

Year	**Crop season**		
	Kharif	***Rabi***	***Summer***
2013-14	Soybean	Wheat	Fallow
2014-15	Soybean	Wheat	Fallow
2015-16	Soybean	Wheat	Fallow
2016-17	Soybean	Present investigation	Fallow
2017-18	Soybean	Present investigation	Fallow
2017-18	Soybean	-	-

3.5 Experimental Details

	Treatment details	Dose (*g a.i.* ha^{-1})
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% WG with surfactant	14.38
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% WG with surfactant	19.17
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% WG with surfactant	23.96
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% WG without surfactant	14.38
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% WG without surfactant	19.17
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% WG without surfactant	23.96
T_7	Pyroxsulam 4.5% OD with surfactant	18.75
T_8	Halauxifen-methyl 10.42% WG with surfactant	5.21
T_9	Sulfosulfuron + Metsulfuron – methyl 80 WG with Surfactant	32
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% WG with surfactant	47.93
T_{11}	Hand weeding Twice	30 & 60 DAS
T_{12}	Control	-

3.6 Other Experimental details

Gross plot size:	5.00 m x 3.15 m
Net plot size:	4.00 m x 2.15 m
Distance between replication:	1.50m
Distance between plots:	1.00m
Total number of plots:	36
Variety:	GW 273
Seed rate:	100 kg ha^{-1}.
Recommended dose of fertilizers:	120:60:40 N, P_2O_5 and K_2O kg ha^{-1}
Spacing (R×R):	22.5 cm
Sowing date 2016 – 17 (first year):	29.11.2016
Harvesting date 2016 - 17:	30.03.2017
Sowing date 2017- 18 (second year):	25.11.2017
Harvesting 2017- 18:	29.03.2018

The wheat variety GW 273 was grown in the experimental field with recommended package of practices during both *Rabi* season of 2016-17 and 2017-18. A field experiment was laid out in a randomized block design comprising of twelve treatments with three replication as per the plan of layout given in Figure 1. The details of the treatments and field experiments are given below.

3.7 Varietal Characteristics

The wheat variety GW 273 has been developed by Wheat Research Station, Gujrat Agriculture University, Vijapur, Gujarat. It is suitable for Central zone, comprising of MP, Gujrat, Southern and Western Rajasthan and Bundelkhand area of UP. Under irrigated timely sown high fertility conditions. The average plant height is 96 cm. Waxiness present on flag leaf, leaf sheath and peduncle. The distinguishing morphological character of the variety is long parallel ear head with dense arrangement of spikelets. Colour of awns and spikelet is dirty white at maturity. Resistance to leaf as well as stem rust which are important diseases of Central zone. It has also very good resistance to leaf blight and karnal bunt. It takes generally 63 days for heading and 113 days for maturity (range 91-136). The test weight of the variety is 47 g. The grain colour is amber, hard textured with oval shape. The yield potential of the variety is 5.5-6.0 t ha^{-1}.

3.8 Cultural practice

3.8.1 Land preparation

A pre-sowing irrigation was given one week before the preparation of land. Preparation of land was done by using cultivator once, disc harrow twice and then it was leveled well to obtain a good seed bed. The field was made almost free from crop stubbles to maximum extent. The experiment was laid out according to the plan of layout by marking corners of the required dimensions. The main and secondary irrigation channels were prepared in between the replications to facilitate the irrigation.

Table 3.4. Schedule of various operations performed during investigation

Operations	Dates		Remark
	2016-17	2017-18	
Land preparation	15.11.2016	13.11.2017	Harrowing With cultivator and disc harrow
Layout of experiment and preparation of channels *etc.*	20.11.2016	22.11.2017	Manually
Seed treatment with vitavex	29.11.2016	25.11.2017	Manually
Sowing with basal dressing of fertilizer	29.11.2016	25.11.2017	Manually
Light irrigation for Germination	29.11.2016	25.11.2017	Manually
First irrigation	20.12.2016	15.12.2017	Manually
First top dressing of urea	23.12.2016	18.12.2017	Manually
Hand weeding at 30 DAS in hand weeded plots	29.12.2016	24.12.2017	Manually by Khurpi
Application of herbicides as post emergence	02.01.2017	30.12.2017	Manually by Knapsack sprayer with flat fan nozzle
Second irrigation	0401.2017.	01.01.2018	Manually
Second top dressing of Urea	05.01.2017	02.01.2018	Manually
Third irrigation	01.02.2017	29.01.2018	Manually
Fourth irrigation	25.02.2017	22.02.2018	Manually
Fifth irrigation	10.03.2017	12.03.2018	Manually
Harvesting	30.03.2017	29.03.2018	Manually by sickle
Threshing and winnowing			Manually

3.8.2 Fertilizer application

The crop was given a recommended dose of nutrients *i.e.* 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} through urea, single super phosphate and muriate of potash, respectively. The full quantity of P_20_5 and K_20 along with half of the dose of N_2 was applied at the time of sowing. The remaining quantity of N was top dressed in two equal splits doses one day after the first and second irrigation.

3.8.3 Seed rate, seed treatment and method of sowing

The certified seed of wheat variety GW 273 having good germination percentage (95%) was sown in all the plots at the rate of 100 kg ha^{-1} during both the year. The seeds were treated before sowing with vitavex 2.5 g kg^{-1} of seed to make them free from seed borne diseases. Treated seeds of wheat were sown uniformly in lines at a row spacing of 22.5 cm manually. The seeds were covered after sowing with loose soil to save moisture loss.

3.8.4 Irrigation

Five irrigations were given to the crop at all the critical stages *viz*., crown root initiation, maximum tillering, late jointing, flowering and milking stage. However, a shallow one come up irrigation was given immediately after sowing to the wheat crop in all the plots just to facilitate proper germination of wheat seeds

3.8.5 Weed control

3.8.5.1 Control (Unweeded check)

The weeds were allowed to grow along with the wheat crop and no herbicides were applied to control the associated weeds with wheat in weedy check plots.

3.8.5.2 Hand weeding

Hand weeding was done twice as per treatment manually with the help of khurpi at 30 and 60 days after sowing to keep crop free from weeds during critical period of crop-weed competition.

3.8.5.3 Application of herbicide

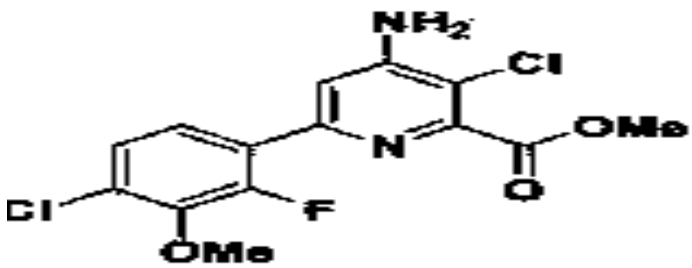
The quantity of different herbicides for the respective plots was determined according to the active ingredient present in the commercial products. The spraying of herbicides was done by mixing the exact quantity of herbicides in measured quantity of water at the rate of 500 liters ha^{-1}. The measured quantity of herbicide and water for each plot was mixed thoroughly before spraying. Herbicides were applied in the respective plots by knapsack sprayer using flat fan nozzle. Fresh solution for individual plot was prepared each time separately. After completing the spray of one herbicide in all the three replications, the sprayer was washed thoroughly with detergent and rinsed finally with fresh water before making the solution of another herbicide.

3.8.5.4 Herbicide details:

Halauxifen-methyl

Halauxifen- methyl is an herbicide used in post emergence application to control annual broad leaf weeds with utility of multiple crops. Its chemical name methyl 4-amino–3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl)-2-pyridine carboxylate picolinic acid and trade name Quelex. It inhibits binds to protein receptor sites that normally regulate plant processes. Halauxifen- methyl is rapidly absorbed by the leaves and roots, moves systemically throughout the target plant in the xylem and phloem and accumulate in the meristematic tissue, where it deregulates growth metabolic pathways.

Structural formula



Molecular formula : $C_{14}H_{11}CL_2FN_2O_3$

Molecular weight : 345.15 g mol^{-1}

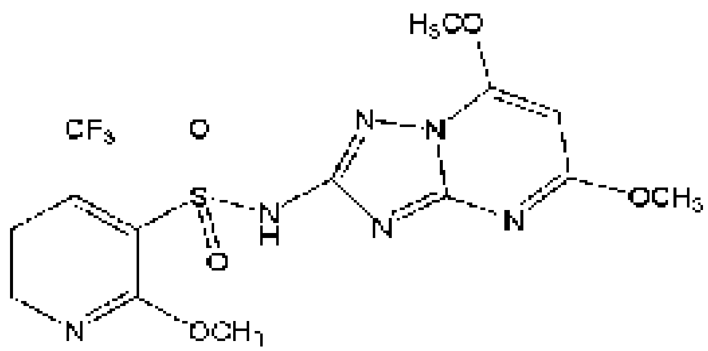
Chemical family : Pyridine carboxylic acid family

Pyroxsulam

Pyroxsulam is a new active constituent. It is in the triazolopyrimidine sulfonamide class of herbicidal compounds. Pyroxsulam inhibits the plant enzyme acetolactate synthase (ALS), which is essential for the synthesis of branched-chain amino acids valine, leucine, and isoleucine. Inhibition of amino acid production subsequently inhibits cell division and causes death in susceptible plants. Pyroxsulam is a systemic, phloem and xylem mobile herbicide that is absorbed via leaves, shoots, and roots. Pyroxsulam is for use in wheat as a post emergence herbicide against a wide range of grass and broadleaf weeds.

Common name	:Pyroxsulam
IUPAC name	:*N*-(5,7-dimethoxy[1,2,4] triazolo[1,5-a]pyrimidin-2-yl)-2- methoxy-4-(trifluoromethyl)pyridine-3-sulfonamide

Structural formula



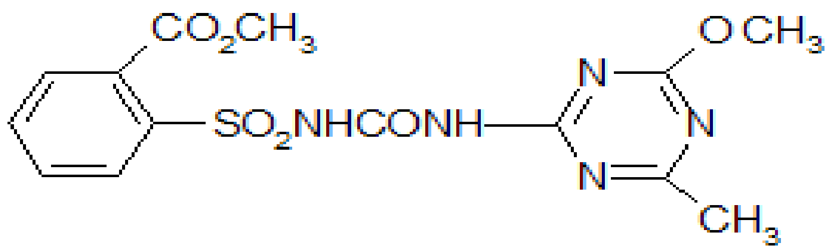
Molecular formula	:$C_{14}H_{13}F_3N_6O_5S$
Molecular Weight	: 434.354 g mol^{-1}
Chemical Family	: Triazolopyrimidine sulfonamide
Mode of Action	: Inhibition of acetolactate synthase (ALS)

Metsulfuron - methyl

Metsulfuron-methyl is a residual sulfonylurea compound used as a selective pre and post emergence herbicide for broadleaf weeds and some annual grasses. It is a systemic compound with foliar and soil activity and it works rapidly after it is taken up by the plant. Its mode of action is by inhibiting cell division in the shoots and roots of the plant, and it is biologically active at low use rates. Metsulfuron-methyl controls a wide range of annual and perennial broad-leaved weeds in wheat, barley, rice and oats, rye, and pastures by either pre- or post-emergence application, at 4 - 7.5 g ha^{-1}.

Chemical Name	:2-[[[[(4, 6-dimethoxy-2-pyrimidinyl) amino] carbonyl] amino] sulfonyl]-4-[[(methylsulfonyl) amino] methyl] benzoic acid (pyrimidinyl-sulfonylurea herbicides)
IUPAC Name	:2-[(4,6-dimethoxy-pyrimidin-2-ylcarbamoyl) sulfamoyl]-α- (methanesulfonamido)-*p*-toluic acid and in trade it is known as Almix.

Structural formula



Molecular weight - 381.4 g mol^{-1}

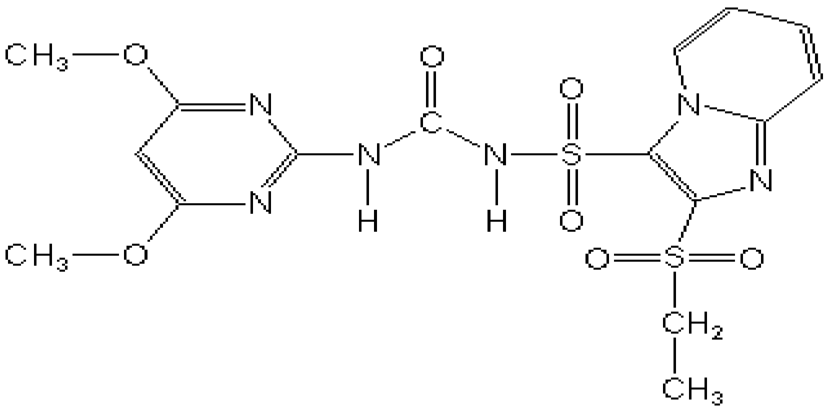
Molecular formula - $C_{14}H_{15}N_5O_6S$

Chemical family – Sulfonylureas.

Sulfosulfuron

It is most potent in array of grass killer. It is a post emergence herbicide. Its chemical name is 1-(2-ethylsulfonylimidazol [1, 2-a] pyridine -3-ylsulfonyl)-3-(4) 6-dimethoxypyrimidin-2-yl) urea and in trade, it is known as Leader 75%.

Structural formula



Common Name **:** Sulfosulfuron

IUPAC name : 1-(2-ethylsulfonylimidazol {1,2-a} phridine-3-solfonyl)- 3-(4-6-dimethoxypryimidine-2-xl) urea.

Molecular weight : 470.48 g mol^{-1}

Molecular formula : $C_{l6}H_{18}N_6O_7S_2$

Mode of action:

Inhibits acetolactate synthase. (ALS), also called acetohydroxy acid synthase (AHAS), a key enzyme in the biosynthesis of the branched chain amino acids isoleucine, leucine and valine.

3.8.6 Harvesting

Harvesting of full matured crop was done manually with the help of sickle as per the treatments. Firstly, harvesting of crop from the border area was done in all plots. Two border rows from both sides of each plots and 50 cm area in both ends of allows were harvested under border area. The harvested produce from border area was removed from the experimental plots by leaving the net plot area intact under each treatment. After this, harvested produce of each plot was allowed to sun drying for 3 days in irrespective plots. Then plot wise produce was tied into bundles and tagged with luggage label for demarcation. After this, harvested produce weighted on spring balance plot wise before transportation to the threshing floor.

3.8.7 Threshing and Winnowing

Sundried produce of each plot was threshed separately on trampoline by beating with wooden sticks. The produce, thus obtained was winnowed by hand winnower (Supa) and cleaned produce was weighed on double pan balance in kg plot^{-1}. The weight of the grains obtained from five plants taken off earlier for biometric studies, was also included in the yield of respective plots.

3.8.8 Experimental observations

Biometric observations were made on weeds as well as on crop and are presented below:

3.8.8.1 Study on weeds

3.8.8.1.1 Weed dynamics

The existence and extent of species wise weed infestation in wheat crop under different weed control treatments were studied as per following details.

3.8.8.1.2 Weed density and relative weed density

The observations on density of major weeds *viz*., *Cyperus iria*, *Medicago denticulata*, *Cichorium intybus*, *Chenopodium album*, *Anagallis arvensis* and *Medicago truncatula* were recorded at before application, 30, 60 days after application and at harvest by quadrat count method. The quadrat of 0.25 m^2 (0.5 m x 0.5 m) was randomly thrown at four places in each plot first time at before application and then it was marked by fixing wooden sticks for subsequent observations. Species wise weed count and total number of weeds per meter square were recorded. The percentage composition of weed flora was estimated from weedy check. The relative density of weeds was worked out as per formula proposed by Misra (1968)-

$$\text{Relative Density (\%)} = \frac{\text{Number of individuals of the same species}}{\text{Number of individuals of all species}} \times 100$$

3.8.8.1.3 Weed biomass (g m^{-2})

The weed biomass was collected at before application, 30, 60 days after application and at harvest of the crop. Ten plants of individual weed species were removed outside of the net area of each plot at before application, 30, 60 days after application and at harvest. The weeds were kept in paper bags and dried in oven at 60°C till the constant weight was achieved. Dry weight was recorded on electronic balance. The average dry weight of individual weed species was multiplied to their respective density to achieve the dry weight of individual weed species (g m^{-2}). Later on, it was converted into kg ha^{-1}.

3.8.8.1.4 Weed control efficiency (WCE %)

It is the efficiency of treatment expressed in percentage for controlling weeds in comparison to weedy check plots. The total weed biomass obtained before harvest was utilized to determine the weed control efficiency of various treatments and was worked out on the basis of the formula suggested by Mani *et al*. (1973).

$$\text{WCE (\%)} = \frac{DW_C - DW_T}{DW_C} \times 100$$

Where,

DW_C = Dry weight of weeds in weedy check plot

DW_T = Dry weight of weeds in treated plot

3.8.8.2 Pre-harvesting observations

3.8.8.2.1 Plant population

Initial and final plant population of crop plant was taken at 15 days after sowing (DAS) and just before harvesting, respectively, from one meter running row length randomly from 5 rows in each plot and then averaged out. After this, plant population per meter square was determined for each plot by multiplying with number of rows in 100 cm or 1 m.

3.8.8.2.2 Plant height (cm)

Five plants were selected randomly in each plot and tagged for recording various observations. The height of marked plants was taken from the base up to tip of the new leaf and up to base of ear after emergence of ear head with the help of meter scale. This observation was recorded at 30 days interval in each plot starting from 30 DAS up to the harvesting of the crop.

3.8.8.2.3 Number of tillers (meter^{-2})

The number of tillers per meter row length was counted from five randomly selected rows in each plot at 30 and 60 DAS. Then mean number of tillers per meter row length was computed for all treatments in both the season. Finally, mean values were multiplied with number of rows in one meter area to get the number of tillers per meter square.

3.8.8.2.4 Number of leaves per plant

The number of leaves per plant were counted in all five tagged plants in each plot at 30, 60, 90 DAS and then mean number of leaves plant^{-1} were computed.

3.8.8.2.5 Growth analytical studies

The growth analytical study was made with regard to leaf area index at 30, 60 and 90 DAS while crop growth rate and relative growth rate at 30-60 and 60-90 DAS.

3.8.8.2.6 Leaf area (cm^2)

The leaf area of three leaves (upper, middle and lower) from five randomly, selected plants were recorded with the help of leaf area meter (Model Cl-203) at 30, 60 and 90DAS. The mean was computed. After this, total leaf area per plant was worked out by multiplying the mean leaf area with number of leave plant^{-1}. It was converted into leaf area index in the formula of Watson 1952.

3.8.8.2.7 Leaf area index (LAI)

The mean was computed. After this, total leaf area per plant was worked out by multiplying the mean leaf area with number of leave plant^{-1}. LAI is the leaf area (A) or the assimilatory surface area over a certain ground area (P) and was calculated by the formula given by Gardner *et al*. (1985)

$$LAI = \frac{A}{P}$$

Where, A = Leaf area P = Ground area

3.8.8.2.8 Chlorophyll content (%)

Chlorophyll content was measured at 30, 60 and 90 DAS with the help of handheld chlorophyll meter (FT Green LLC, Wilmington, DE, USA). The readings of chlorophyll content of green leaves were noted from three leaves (upper, middle and lower) of five randomly selected plants. They were averaged across each plot and expressed as chlorophyll reading plant^{-1}.

3.8.8.2.9 Crop dry weight (g)

The crop dry weight was recorded at 30, 60, 90 DAS and at harvest. Five plants from each plot were removed from the second last line of plots from either side and the root portion was removed. The samples were initially dried in air and later on in the oven at 60°C till constant weight are achieved. After drying, the mean dry weight was determined and dry matter accumulation m^{-2} was computed by multiplying the plant population m^{-2}.

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

The gain in weight of community of plant in a unit land area in a unit time is termed as crop growth rate and expressed in g m^{-2} day^{-1}. It was calculated as per the following formula suggested by Potter and James (1977).

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

Where,

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

3.8.8.2.11 Relative growth rate (g g^{-1} day^{-1})

It is expressed as the dry weight increase in a time interval in relation to the initial weight. The mean relative growth rate is calculated from measurement at time t1 and t2 and expressed as g g^{-1} day^{-1} Beadle, 1985).

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

Where,

W_1, W_2 are dry matter and at time t_1, t_2, respectively.

3.8.8.3 Post-harvest studies

The post-harvest observations on various yield attributing characters were recorded from five randomly selected plants in each plot.

3.8.8.3.1 Number of effective tillers (m^{-2})

The total number of ear bearing tillers from five randomly selected rows was counted in each plot at the time of harvesting. Then mean number of effective tillers m^{-1} row length was computed for all treatments in both the season. Finally, mean values were multiplied with number of rows in one meter area to get the number of effective tillers m^{-2} area.

3.8.8.3.2 Length of ear head (cm)

Ten ear heads were selected randomly from each plot at the time of harvesting. The length of each ear head was measured from its base to the tip with the help of scale. Finally, mean length of ear head was calculated for each treatment and presented in centimeter.

3.8.8.3.3 Number of grains per ear head

Grains from each of the ten randomly selected ear heads from each plot were removed and counted manually. Later the mean numbers of grains per ear head were computed dividing the total number of grains with number of ear heads.

3.8.8.3.4 1000-grain weight (test weight g)

Random grain samples were drawn from the heap of the threshed and cleaned produce of each plot. Thousand seeds from each sample were counted and weighed accurately in electronic balance and presented in gram.

3.8.8.3.5 Biological yield (kg ha^{-1})

The harvested produce from each net plot was tied separately into bundles, air-dried and dry weight of bundles was recorded with the help of spring balance in kilogram. Later, it was converted into kg ha^{-1} by multiplying with factor.

3.8.8.3.6 Grain yield (kg ha^{-1})

The grain yield per net plot was recorded after winnowing the produce and sun drying with the help of double pan balance. Finally, grain yield of each plot was converted into grain yield kg h^{-1} by multiplying with appropriate conversion factor.

3.8.8.3.7 Straw yield (kg ha^{-1})

The straw yield was recorded by deducting the grain yield (economic yield) of each plot from the biological yield (bundle weight) of the same plot. This was later converted into straw yield kg ha^{-1} by multiplying with same conversion factor which was used in case of grain yield kg ha^{-1}.

3.8.8.3.8 Harvest index (%)

It refers to the ratio of economic yield (grain yield) in the biological yields (grain + straw yields) and it is expressed under a particular treatment in percentage. It was worked out for each plot by using the following formula (Nichiporovich, 1967):-

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

3.8.8.3.9 Weed Index (%)

It refers to per cent reduction in the seed yield under a particular treatment due to the presence o f weeds in comparison to the seed yield obtained in weed free plot *i.e.* hand weeding as suggested by Gill and Kumar (1969). It is expressed in percentage and determined with the formula:

$$\text{WI (\%)} = \frac{X - Y}{X} \times 100$$

Where,

WI = Weed index

X = Seed yield of weed free plot

Y = Seed yield of the treated plot for which weed index is to be worked out

3.8.8.3.10 N, P and K uptake (kg ha^{-1})

For estimation of nitrogen, phosphorous, potassium content (%) in representative samples of grain and straw were taken at the time of threshing and then they were allowed to dry in an oven at 60°c till constant weight. Each dried grain and straw sample was grinded to fine powder in an electrical grinder for chemical analysis to estimate the nutrient contents. From each grind sample, 0.5 g was weighed separately for N analysis and 1 g for P and K analysis. Nutrient content in grain and straw were determined using standard methods given below:

Nitrogen content

Nitrogen was determined through micro Kjeldahl digestion and distillation method (Amma, 1989).

$$\text{N uptake by crop (kg ha}^{-1}) = \frac{\text{N content in total yield (Straw + grain) \% X Total yield (Straw + grain) (kg ha}^{-1})}{100}$$

Phosphorus content

Phosphorus was estimated by Vanadomolybdo phosphoric yellow colour method (Koenig and Johnson, 1942).

$$\text{P uptake by crop} = \frac{\text{P content in total yield (Straw + grain) \% X Total yield (Straw + grain) (kg ha}^{-1})}{100}$$

N uptake by crop (kg ha^{-1}) =

Potash content

Potassium was estimated through Flame Photometer (Black, 1965).

$$\text{K uptake by crop} = \frac{\text{K content in total yield (Straw + grain) \% X Total yield (Straw + grain) (kg ha}^{-1})}{100}$$

N uptake by crop (kg ha^{-1}) =

3.8.8.3.11 Protein yield

The nitrogen content of seeds was estimated by micro – Kjeldahl method. The protein percentage was calculated by using following formula:

Total Protein = Total nitrogen x 6.25

Protein yield (kg ha^{-1}) =Grain yield (kg ha^{-1}) X Protein percent in grain/100

3.8.8.3.12 Change in chemical soil

The soil samples were taken from each plot after completion of both crop seasons during the investigation to assess the effect of different treatments on the changes in chemical properties of soil over the initial status. These soil samples were drawn with the help of screw soil auger from different locations to a depth of 15 cm from each plot and tagged with luggage labels. Sample was taken from all three replications were mixed together treatment wise to obtain a composite sample. After proper drying, the composite sample was powdered finally with the help of mortar and pestle and sieved through 2 mm sieve. Then, the sample was subjected to analysis for various chemical properties just to know changes occurred due to different treatments.

3.8.8.4 Economics of the treatments

Economic analysis of wheat crop was made separately for each treatment to assess the practical utility of various treatments for the grower’s point of view. Gross monetary returns (GMR) as value of the produce and total cost of cultivation were determined per hectare area basis. Existing market price of inputs used and outputs obtained under each treatment were taken into consideration to calculate these values. The net monetary returns (NMR) for each treatment were computed by deducting the cost of cultivation from the value of the produce under a particular treatment. The benefit cost ratio (profitability) under each treatment was also worked out by using the following formula:

Cost of cultivation

Cost of cultivation was calculated by adding cost of items used in cultivation (₹ ha^{-1}) while total expenditure was calculated by adding cost of cultivation with the treatment cost (Appendix-xii).

Net Monetary Returns

The net monetary returns (NMR) per hectare under each treatment were determined by subtracting the cost of cultivation of a particular treatment from the GMR of the same treatment.

Net return (₹ha^{-1}) = Gross monetary return (₹ha^{-1}) – Cost of cultivation (₹ha^{-1})

B:C Ratio

Benefit cost ratio is the index indicating monetary gains over each rupee investment under different treatments and it is also termed as profitability. It was calculated by using the following formula:

$$\text{B:C ratio} = \frac{\text{Gross monetary returns (₹ ha}^{-1}\text{)}}{\text{Total cost (cost of cultivation + Cost of treatments) (₹ ha}^{-1}\text{)}}$$

3.8.9 Observation recorded on succeeding soybean crop

3.8.9.1 Pre harvest studies

3.8.9.1.1 Plant population (m^{-2})

Initial and final plant population of crop plants were taken at 15 DAS and just before harvesting respectively, from one meter running row length in 4 rows randomly in each plot and then averaged out. After this, plant population per meter square was determined for each plot.

3.8.9.1.2 Branches $plant^{-1}$

The number of branches per plant were counted on the 5 tagged plants in each plot at 30, 60, 90 DAS, harvest and then mean was determined for each treatment for all stages.

3.8.9.2 Post-harvest Observations

3.8.9.2.1 Number of pods plant^{-1}

Numbers of pods were removed from tagged five plants in each plot at harvest and then counting of these pods was made for each plot. Finally, mean was computed by dividing the total values with five.

3.8.9.2.2 Number of seeds pod^{-1}

Random samples of 10 pods were drawn from the harvested produce of each plot to work out the mean number of seeds per pod.

3.8.9.2.3 Seed index (g)

The hundred seeds were randomly taken from the finally cleaned produce of each plot for recording seed index. Then weight of 100-seeds of each plot was recorded separately on an electrical balance in the laboratory.

3.8.9.2.4 Seed yield (kg ha^{-1})

The seed yield from each net plot was recorded after winnowing the produce, with the help of double pan balance. Finally, seed yield of each plot was converted into seed yield per hectare by multiplying with appropriate conversion factor.

3.8.9.2.5 Haulm yield (kg ha^{-1})

The haulm yield per plot was determined by subtracting seed yield (economical yield) of each plot from biological yield (bundle weight) of the same plot. This was later on converted in to haulm yield per hectare by multiplying with the same conversion factor which was used in case of seed yield per hectare.

3.8.9.2.6 Harvest index (%)

It is the ratio of economic yield to the biological yield. It was determined with the help of following formula and expressed in percentage as follows:

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

3.8.9.2.7 Toxicity

The herbicide toxicity on crop stand and growth was recorded 15, 30 and 45 DAS by rating scale (0-10). While, zero rating represented no injury to crop plants and 10 represented complete destruction.

Table 3.6. Visual phytotoxicity scoring on succeeding crop

Effect	Rating	Description crop
None	0	No injury, normal
	1	Slight stunting, injury and discoloration
	2	Some stand loss, stunting and 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

3.8.9 Statistical analysis:

The data recorded during the course of investigation was subjected to statistical analysis by “Analysis of variance technique” (Gomez and Gomez, 1984). The significant and non-significant treatment effects were judged with the help of ‘F’ (variance ratio) table. The significant differences between the means were tested against the critical difference at 5% probability level. For testing the hypothesis, the following ANOVA table (3.5) was used.

Table 3.5. Skeleton of ANOVA table

Source of variation	Degree of freedom	Source of variation	M.S.S.	F_{Cal}	F_{Tab} at 5%
Replications	2				
Treatment	11				
Error	22				
Total	35				

RESULTS

Results of the field experiment entitled "**Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat**" are briefly elucidated in this chapter. The observations recorded on growth, yield attributes, grain yield, weed population, dry weight of weeds, weed index, weed control efficiency, and data on effect of herbicidal treatment on succeeding soybean crop were subjected to statistical analysis and "Analysis of variance" has been furnished in Appendices I to XLVI the results have also been presented graphically wherever necessary. The efficacy of various treatments was adjudged by a comparative assessment of growth, yield attributes, yield and other characters. All findings pertaining to different treatments are described in the following heads.

4.1 Study on weeds

4.2 Study on crop

4.3 Nutrient uptake by crop

4.4 Economics

4.5 Study on succeeding soybean crop

4.1 STUDY ON WEEDS

Study on associated weed flora, density and relative density of dominant weeds in weedy check plots, density and dry weight of individual weed species under different treatments were recorded at different intervals *viz*., before herbicide application, 30 DAA, 45 DAA, and at harvest of the crop but the observation on dominant weed species and total weeds recorded at 30 DAA have been interpreted in the forthcoming pages. The remaining data are cited in the appendices XII-XXVI for perusal.

4.1.1 Associated Weed Flora

4.1.1.1 Density

It is evident from the data given in Table 4.1 that density of dicot weeds in weedy plots were higher (201.3 and 210.8 m^{-2}) first year and second year respectively, as compared to monocot weeds (27.3 and 28.7 m^{-2}) during both the years of experimentation at 30 days after application (DAA), indicating predominance of dicoct weeds in the experimental field with wheat crop. Whereas, *Medicago denticulata* was dominant among the dicots (66.0 and 76.7 m^{-2}). Besides these, *Medicago truncatula* (53.3 and 47.3 m^{-2}), *Chenopodium album* (32.0 and 36.0 m^{-2}), *Anagallis arvensis* (25.3 and 32.0 m^{-2}), *Cichorium intybus* (24.7 and 28.0 m^{-2}), also marked their presence in good numbers in the experimental field. (Figure 4.1)

4.1.1.2 Relative density

It is evident from the data given in Table 4.1 that relative density of dicot weeds in weedy plots were higher (88.1 and 88.3 %) first year and second year respectively, as compared to monocot weeds (11.9 and 11.7 % respectively) during both the years of experimentation at 30 days after application (DAA), indicating predominance of dicoct weeds in the experimental field. Whereas, *Medicago denticulata* was dominant among the dicots (28.9 and 29.9 % respectively). Besides these, *Medicago truncatula* (23.3 and 21.1 % respectively), *Chenopodium album* (14.0 and 14.2 % respectively), *Anagallis arvensis* (11.1 and 12.0 % respectively), *Cichorium intybus* (10.8 and 11.1 % respectively), also marked their presence in good numbers. (Figure 4.2)

Table 4.1 Weed density and relative density of associated weeds in weedy check plots at 30 DAA in wheat during *Rabi* seasons (2016-17 and 2017-18)

Weed flora	Common name	Family	Weed density (m^{-2})		Relative density (%)	
			2016-17	**2017-18**	**2016-17**	**2017-18**
Monocot *Cyperus iria*	Rice flat sedge	Cyperaceae	27.3	28.7	11.9	11.7
	Sub – total		27.3	28.7	11.9	11.7
Dicots						
Medicago denticulata	Toothed bur clover	Fabaceae	66.0	76.7	28.9	29.9
Cichorium intybus	Blue daisy	Asteraceae	24.7	28.0	10.8	11.1
Anagallis arvensis	Blue pimpernel	Primulaceae	25.3	32.0	11.1	12.0
Chenopodium album	Common lambsquarter	Chenopodiaceae	32.0	36.0	14.0	14.2
Medicago truncatula	Barrel clover	Fabaceae	53.3	47.3	23.3	21.1
		Sub - total	201.3	210.8	88.1	88.3
		Grand total	218.6	238.8	100	100

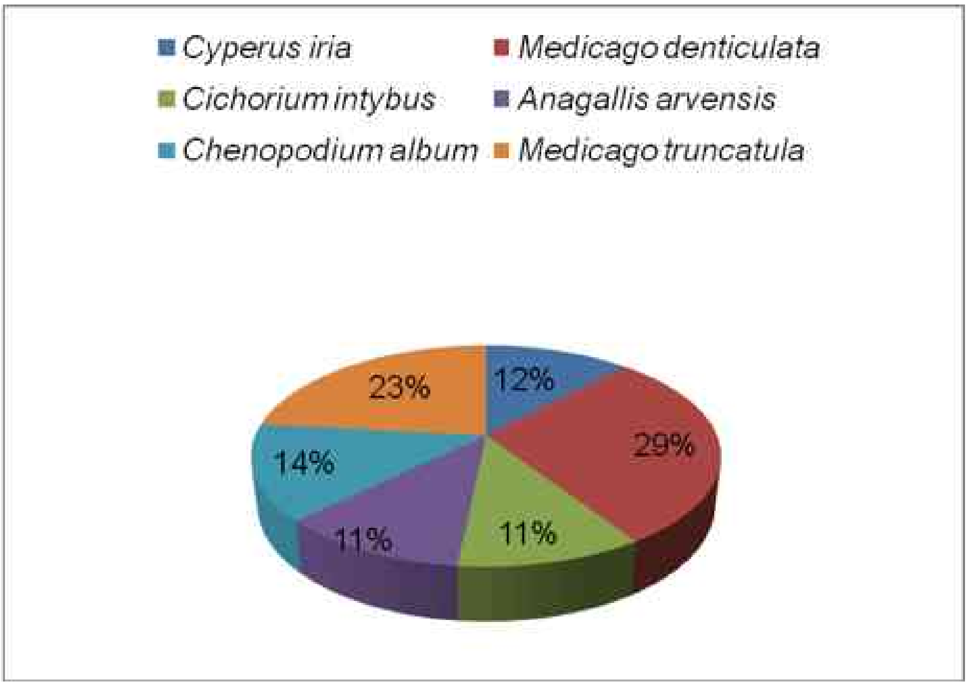


Fig. 4.1. Weed density and relative density of different weed flora in weedy check plot during 2016-17

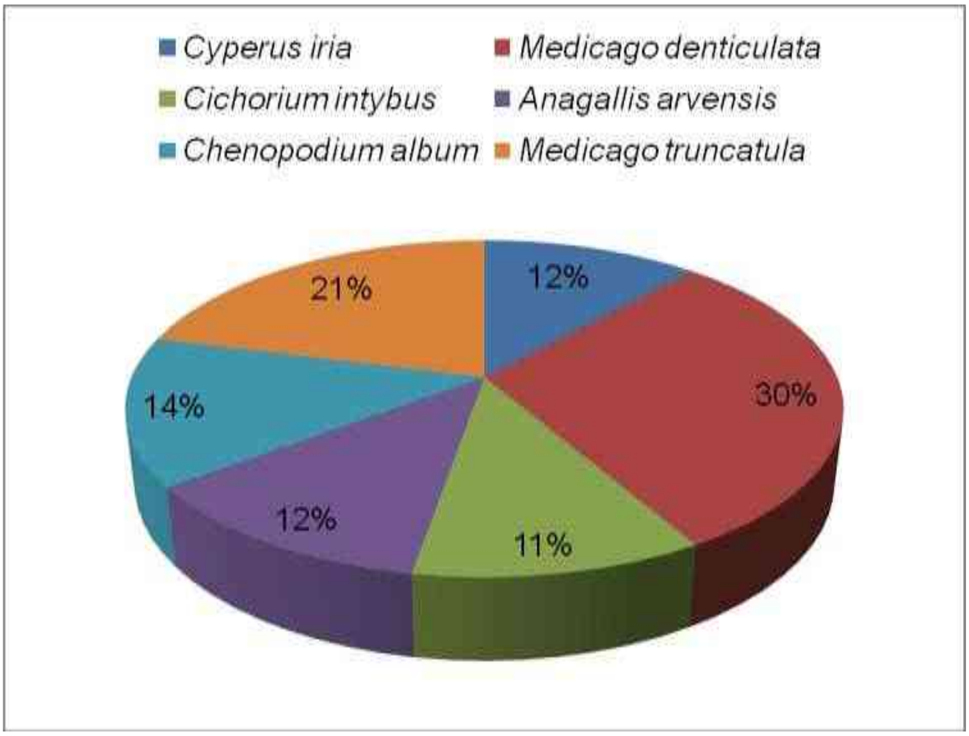


Fig. 4.1 Weed density and relative density of different weed flora in weedy check plot during 2917-18

4.1.2 Effect on Weed Density

The data recorded on density of associated weeds *viz., Cyperus iria, Cichorium intybus Anagallis arvensis*, *Medicago denticulata*, *Chenopodium album* and *Medicago truncatula* at 30 DAA and harvest during both the years (2016-17 and 2017-18) as influenced by various weed control treatments. But species wise mean data on density of associated weeds for two *Rabi* seasons at 30 DAA are presented in (Table 4.2 to 4.7). The comparison among the herbicidal treatment means have been made based on transformed values ($\sqrt{x+0.5}$) in case of weed parameters only.

Cyperus iria

The mean data of two *Rabi* seasons (2016-17 and 2017-18) pertaining to density of C*yperus iria* as influenced by different weed control treatments at 30 DAA are presented in Table 4.2 and graphically represented in Figure 4.2.

It is evident from the data that the different weed management practices significantly influenced the density of *Cyperus iria* over weedy check during both the years of experimentation. The highest weed density was observed in weedy check (5.36 m^{-2}), whereas, hand weeding twice (30 and 60 DAS) recorded lowest mean density (2.14 m^{-2}). Among the herbicidal treatments, post - emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lower dose 14.38 g *a.i.* ha^{-1} caused (3.31and 3.41 m^{-2}) reduction in the density of *Cyperus iria* over weedy check. However, the efficacy of Halauxifen – methyl 6.95 % + Pyroxsulam 25% was further improved with corresponding increase in the doses of application from 14.38 to 23.96 g *a.i.* ha^{-1} with surfactant, being maximum when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant applied at 23.96 g *a.i.* ha^{-1} (2.88 m^{-2}) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.17 g *a.i*. ha^{-1} (3.00 m^{-2}) and Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 23.96 g *a.i*. ha^{-1} (3.08 m^{-2}). Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to without surfactant. The application of single herbicides was less effective as compared to mixed application but it was significantly superior over weedy check.

Table 4.2. Effect of different herbicidal treatments on density of *Cyperus iria* (m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	3.21 (9.3)	3.40 (10.7)	3.31 (10.0)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.88 (7.3)	3.11 (8.7)	3.00 (8.0)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.76 (6.7)	2.99 (8.0)	2.88 (7.4)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	3.31 (10.0)	3.51 (11.3)	3.41 (10.7)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	3.11 (8.7)	3.31 (10.0)	3.21 (9.4)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.88 (7.3)	3.27 (9.7)	3.08 (8.5)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	3.41 (10.7)	3.70 (12.7)	3.56 (11.7)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	3.51 (11.3)	3.60 (12.0)	3.56 (11.7)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	3.31 (10.0)	3.56 (10.7)	3.44 (10.9)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2.51 (5.3)	2.65 (6.0)	2.58 (5.7)
T_{11}	Hand weeding twice	30 & 60 DAS	2.07 (3.3)	2.21 (4.0)	2.14 (3.7)
T_{12}	Control (weedy check)	-	5.31 (27.3)	5.41 (28.7)	5.36 (28.0)
SEm ±			**0.07**	**0.19**	**0.13**
CD (P=0.05)			**0.20**	**0.57**	**0.38**

Medicago denticulata

The mean data of both *Rabi* seasons (2016-17 and 2017-18) related to density of *Medicago denticulata* as affected by different herbicidal treatments at 30 DAA are given in Table 4.3 and graphically represented in Figure 4.3. The density of *Medicago denticulata* was significantly influenced by various weed control treatments.

It is obvious from the data that all the herbicidal treatments including hand weeding had lowered the density of *Medicago denticulata* significantly at 30 DAA as compared to weedy check during both the years. The highest weed density was observed in unweeded control (8.49 m^{-2}) however; hand weeding twice (30 and 60 DAS) recorded lowest mean density (2.58 m^{-2}). Among the herbicidal treatments, post - emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lower dose 14.38 g *a.i.* ha^{-1} caused (4.74 and 4.94 m^{-2}). However, the efficacy of Halauxifen – methyl 6.95 % + Pyroxsulam 25% was further improved identically with corresponding increase in the doses of application from 14.38 to 23.96 g *a.i.* ha^{-1} with and without surfactant, being maximum when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} (3.36 m^{-2}) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.17 g *a.i*. ha^{-1} (4.37 m^{-2}) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 23.96 g *a.i*. ha^{-1} (4.49 m^{-2}). Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to application of herbicide without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over untreated plot.

Table. 4.3. Effect of different herbicidal treatments on density of *Medicago denticulata* (m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	4.69 (21.0)	4.79 (22.0)	4.74 (21.0)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	4.30 (18.0)	4.43 (18.7)	4.37 (18.4)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	3.46 (11.0)	3.26 (9.7)	3.36 (10.4)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	4.89 (23.0)	4.98 (24.0)	4.94 (23.5)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	4.76 (21.7)	4.58 (20.0)	4.67 (20.9)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	4.47 (19.0)	4.50 (19.3)	4.49 (19.2)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	5.10 (25.0)	5.06 (24.7)	5.08 (24.9)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	8.13 (65.3)	6.57 (42.3)	7.35 (53.8)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	4.93 (23.3)	4.43 (18.7)	4.68 (21.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	3.11 (8.7)	2.83 (7.0)	2.97 (7.9)
T_{11}	Hand weeding twice	30 & 60 DAS	2.58 (5.7)	2.58 (5.7)	2.58 (5.7)
T_{12}	Control (weedy check)	-	8.17 (66.0)	8.80 (76.7)	8.49 (71.4)
SEm ±			**0.21**	**0.22**	**0.22**
CD (P=0.05)			**0.63**	**0.66**	**0.65**

Cichorium intybus

The mean data of two *Rabi* seasons (2016-17 and 2017-18) pertaining to density of *Cichorium intybus* as influenced by different weed control treatments at 30 DAA are given in Table 4.4 and graphical represented in Figure 4.4.

It is obvious from the data that different weed control treatments caused significant influence on the density of *Cichorium intybus*. The density of *Cichorium intybus* was maximum under weedy check (5.23 m^{-2}). But, there was appreciable reduction in the density of *Cichorium intybus* when weed control measures were adopted. Among the herbicidal treatments, the activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant was poor against *Cichorium intybus* when it was applied at lower dose 14.38 g *a.i.* ha^{-1} as it caused (4.23 and 4.48 m^{-2}) reduction in the density than weedy check. But, the efficacy of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant was further increased with increase in the doses of application from 14.38 to 23.96 g *a.i*. ha^{-1} which reduced the density to the tune of 4.23 and 3.19 m^{-2}, respectively, over its lower dose. However, the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose 23.96 g *a.i*. ha^{-1} proved statistically superior in reducing the density of *Cichorium intybus* over its lower dose (14.23 and 19.17 g *a.i.* ha^{-1}) followed by 19.17 g *a.i.* ha^{-1} Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant application. But, all the herbicidal treatment proved inferior to hand weeding twice (2.34 m^{-2}) in eliminating the density of *Cichorium intybus* as it curbed the density of *Cichorium intybus* to the maximum extent. Ready mixture application of post - emergence herbicide with surfactant gave better response as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over weedy check.

Table 4.4. Effect of different herbicidal treatments on density of *Cichorium intybus* (m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	4.26 (17.3)	4.19 (16.7)	4.23 (17.0)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	3.87 (14.0)	3.74 (13.0)	3.81 (13.5)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	3.27 (9.0)	3.11 (8.7)	3.19 (9.2)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	4.47 (19.0)	4.49 (19.3)	4.48 (19.2)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	4.24 (17.0)	4.04 (15.3)	4.14 (16.2)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	4.02 (15.3)	3.84 (14.0)	3.93 (14.7)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	4.49 (19.3)	4.36 (18.0)	4.42 (18.7)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	5.45 (28.7)	5.03 (24.3)	5.24 (26.5)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	4.18 (16.7)	4.24 (17.3)	4.21 (17.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2.89 (7.3)	2.70 (6.3)	2.80 (6.8)
T_{11}	Hand weeding twice	30 & 60 DAS	2.31 (4.3)	2.37 (4.7)	2.34 (4.5)
T_{12}	Control (weedy check)	-	5.07 (24.7)	5.38 (28.0)	5.23 (26.4)
SEm ±			**0.17**	**0.22**	**0.19**
CD (P=0.05)			**0.49**	**0.64**	**0.57**

Anagallis arvensis

The data on density of *Anagallis arvensis* for both *Rabi* seasons (2016-17 and 2017-18) at 30 DAA under different weed control treatments are given in Table 4.5 and graphically represented in Figure 4.5.

The different weed management practices significantly influenced the density of *Anagallis arvensis* over untreated control during both the years experimentation. It is clear from the data that weed control treatments caused significant variation on the density of *Anagallis arvensis*. The density of *Anagallis arvensis* was recorded maximum (5.44 m^{-2}) under weedy check. The activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant was poor against *Anagallis arvensis* when it was applied at lower dose 14.38 g *a.i.* ha^{-1} (4.03 and 4.22 m^{-2}, respectively), but it was improved significantly when it was applied at higher dose 23.96 g *a.i.* ha^{-1} (2.89 m^{-2}) and proved significantly superior over lower doses of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 14.38 and 19.17 g *a.i.* ha^{-1} (4.03 and 3.65 m^{-2} respectively). However, none of the herbicidal treatment found superior to hand weeding which caused maximum reduction (2.27 m^{-2}) in the density of *Anagallis arvensis* and proved superior to all the herbicidal treatments applied in wheat. Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the weedy check.

Table 4.5. Effect of different herbicidal treatments on density of *Anagallis arvensis* (m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	4.04 (15.3)	4.02 (15.3)	4.03 (15.3)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	3.60 (12.0)	3.65 (12.3)	3.65 (12.2)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.89 (7.3)	2.88 (7.3)	2.89 (7.3)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	4.32 (17.7)	4.12 (16.0)	4.22 (16.9)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	4.00 (15.0)	4.08 (15.7)	4.04 (15.4)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	3.70 (12.7)	3.96 (14.7)	3.83 (13.7)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	4.51 (19.3)	4.36 (18.0)	4.44 (18.7)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	4.90 (23.0)	4.99 (24.0)	4.95 (23.5)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	3.99 (15.0)	4.36 (18.0)	4.18 (16.5)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2.44 (5.0)	2.52 (5.3)	2.48 (5.2)
T_{11}	Hand weeding twice	30 & 60 DAS	2.16 (3.7)	2.37 (4.7)	2.27 (4.2)
T_{12}	Control (weedy check)	-	5.13 (25.3)	5.74 (32.0)	5.44 (28.7)
SEm ±			**0.10**	**0.16**	**0.13**
CD (P=0.05)			**0.29**	**0.46**	**0.38**

Chenopodium album

Density of *Chenopodium album* of both *Rabi* seasons (2016-17 and 2017-18) at 30 DAA as influenced by different herbicidal treatments are given in Table 4.6 and graphically represented in Figure 4.6.

It is obvious from the data that all the herbicidal treatments including hand weeding had lowered the density of *Chenopodium album* significantly at 30 DAA as compared to weedy check. Among the herbicidal treatments, the activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant was poor against *Chenopodium album* when it was applied at lower dose 14.38 g *a.i.* ha^{-1} as it caused (4.00 and 4.30 m^{-2} respectively) reduction in the density. But reduction was more pronounced when Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant with increase in the doses of application from 19.17 to 23.96 g *a.i.* ha^{-1} which reduced the density to the tune of (3.76 and 2.82 m^{-2} respectively) over its lower dose. However, the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose 23.96 g *a.i.* ha^{-1} (2.82 m^{-2}) proved statistically superior in reducing the density of *Chenopodium album* over its lower dose 14.23 and 19.17 g *a.i*. ha^{-1}. But, all the herbicidal treatment proved inferior to hand weeding twice (2.23 m^{-2}) in eliminating the density of *Chenopodium album* as it curbed the density of *Chenopodium album* to the maximum extent. Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the untreated plot.

Table 4.6. Effect of different herbicidal treatments on density of *Chenopodium album* (m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (30 DAA)		
			2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	4.04 (15.3)	3.95 (14.7)	4.00 (15.0)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	3.74 (13.0)	3.78 (13.3)	3.76 (13.2)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.71 (6.3)	2.93 (7.7)	2.82 (7.0)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	4.28 (17.3)	4.32 (17.7)	4.30 (17.5)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	4.04 (15.3)	4.00 (15.0)	4.02 (15.2)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	3.87 (14.0)	3.85 (14.0)	3.86 (14.0)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	4.04 (15.7)	4.12 (16.0)	4.10 (15.9)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	5.47 (29.0)	5.35 (27.)	5.41 (28.4)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	3.87 (14.0)	3.60 (12.0)	3.74 (13.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2.63 (6.0)	2.44 (5.0)	2.54 (5.5)
T_{11}	Hand weeding twice	30 & 60 DAS	2.30 (4.3)	2.16 (3.7)	2.23 (4.0)
T_{12}	Control (weedy check)	-	5.73 (32.0)	6.06 (36.0)	5.90 (34.0)
SEm ±			**0.14**	**0.17**	**0.16**
CD (P=0.05)			**0.42**	**0.51**	**0.47**

Medicago truncatula

The mean data on density of *Medicago truncatula* for two *Rabi* seasons (2016-17 and 2017-18) at 30 DAA under different weed control treatments are given in Table 4.7 and graphically represented in Figure 4.7.

The different weed management practices significantly influenced the density of *Medicago truncatula* over untreated control during both the year of experimentation. It is evident from the data that weed control treatments caused significant variation on the density of *Medicago truncatula* at 30 DAA. The density of *Medicago truncatula* was maximum under weedy check (7.15 m^{-2}) at 30 DAA, where weeds were not controlled throughout the crop season. The effect of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant was poor against *Medicago truncatula* when it was applied at lower dose 14.38 g *a.i.* ha^{-1}, but it was improved significantly (3.06 m^{-2}) when it was applied at higher dose 23.96 g *a.i.* ha^{-1} and proved significantly superior over lower doses of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant 14.38 and 19.17 g *a.i.* ha^{-1}. However, none of the herbicidal treatment found superior to hand weeding twice (30 and 60 DAS) which caused maximum (2.35 m^{-2}) reduction in the density of *Medicago truncatula* and proved superior to all the herbicidal treatments applied in wheat. Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over weedy check.

Table 4.7. Effect of different herbicidal treatments on density of *Medicago truncatula* (m^2) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weeds (m^{-2}) (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	4.12 (16.0)	4.04 (15.3)	4.08 (15.7)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	3.95 (14.7)	3.87 (14.0)	3.91 (14.4)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	3.00 (8.0)	3.11 (8.7)	3.06 (8.4)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	4.43 (18.7)	4.35 (18.0)	4.39 (18.4)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	4.20 (16.7)	4.12 (16.0)	4.16 (16.4)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	4.03 (15.3)	3.95 (14.7)	3.99 (15.0)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	4.58 (20.0)	4.51 (19.3)	4.55 (19.7)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	5.74 (32.0)	6.29 (38.7)	6.02 (35.4)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	4.51 (19.3)	4.43 (18.7)	4.47 (19.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2.64 (6.0)	2.63 (6.0)	2.64 (6.0)
T_{11}	Hand weeding twice	30 & 60 DAS	2.38 (4.7)	2.31 (4.3)	2.35 (4.5)
T_{12}	Control (weedy check)	-	7.36 (53.3)	6.94 (47.3)	7.15 (50.3)
SEm ±			**0.13**	**0.16**	**0.15**
CD (P=0.05)			**0.39**	**0.46**	**0.43**

4.1.3 Dry weight of weeds

Dry matter accumulation per unit area is an indication of weed growth under particular treatment. The observation on dry weight of associated weeds *viz., Cyperus iria, Medicago denticulata, Anagallis arvensis*, *Cichorium intybus*, *Chenopodium album* and *Medicago truncatula* were made at 30 days after application (DAA) of wheat during both the years 2016-17 and 2017-18. The associated weeds with wheat were separated out species wise and dry weight was recorded treatment wise after sun drying followed by drying in oven at 60^0C till constant weight was achieved and species wise mean data for two *Rabi* seasons thus obtained at 30 DAA are given in Table 4.8 to 4.13 after square root transformation are cited in Appendix VII to XII.

Cyperus iria

The mean data on the dry weight of *Cyperus iria* of both *Rabi* seasons (2016-17 and 2017-18) at 30 DAA as influenced by different weed control treatments is shown in Table 4.8 and graphically represented in Figure 4.8. The different weed management practices significantly reduced the density of *Cyperus iria* over untreated control during both the years of investigation.

It is clear from the data that weed control treatments had significant influence on the dry weight of *Cyperus iria* at 30 DAA. Data showed that herbicidal treatments including hand weeding twice caused significant reduction on the dry weight of *Cyperus iria* as compared to weedy check. However, the dry weight of this weed was maximum under weedy check (3.11g m^{-2}) due to uninterrupted growth during critical period of crop-weed competition. Among the herbicidal treatments, some reduction in dry weight of this weed was observed with the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at lower dose 14.38 *g a.i.* ha $^{-1}$ (2.18 and 2.32 g m^{-2}) compared to untreated plots. But, reduction in the dry weight of this weed was further improved with corresponding increase in application doses from 19.17 to 23.96 g *a.i.* ha^{-1} being maximum in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i*. ha^{-1} (1.72 g m^{-2}) and was found significantly superior to lower doses 14.38 and 19.17 g *a.i*. ha^{-1}. However, none of the herbicidal treatments surpassed hand weeding twice which lowered the dry weight of *Cyperus iria* to the maximum extent (1.36 g m^{-2}). Ready mixture application of post - emergence herbicide with surfactant gave better result as compare to application without surfactant. The applications of single herbicides were less effective as compared to mixed application but the differences were significantly superior over the weedy check.

Table 4.8. Effect of different herbicidal treatments on dry weight of *Cyperus iria* (g m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weed dry weight (30 DAA)		
			2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.12 (3.0)	2.24 (4.1)	2.18 (3.5)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	1.98 (2.4)	2.04 (3.2)	2.01 (2.8)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	1.72 (2.2)	1.72 (2.0)	1.72 (2.1)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.26 (3.3)	2.37 (4.7)	2.32 (4.0)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.13 (2.9)	2.16 (3.7)	2.15 (3.3)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.07 (2.4)	2.10 (3.4)	2.09 (2.9)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.44 (3.4)	2.38 (4.7)	2.41 (4.1)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	2.40 (3.6)	2.41 (4.8)	2.41 (4.2)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.14 (3.2)	2.18 (3.8)	2.16 (3.5)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1.57 (1.7)	1.53 (1.4)	1.55 (1.5)
T_{11}	Hand weeding twice	30 & 60 DAS	1.32 (1.3)	1.40 (1.0)	1.36 (1.2)
T_{12}	Control (weedy check)	-	3.09 (8.6)	3.13 (8.8)	3.11 (8.7)
SEm ±			**0.09**	**0.08**	**0.09**
CD (P=0.05)			**0.25**	**0.24**	**0.25**

Medicago denticulata

The data on the dry weight of *Medicago denticulata* during both *Rabi* seasons (2016-17 and 2017-18) at 30 DAA was influenced by different herbicidal treatment are given in Table 4.9 and graphically represented in Figure 4.9.

The different weed management practices significantly influenced the dry weight of *Medicago denticulata* over untreated control during both the year of investigation. The highest mean weed dry weight was observed in weedy check (5.55 g m^{-2}) where weed control measures were not adopted, however hand weeding twice (30 and 60 DAS) recorded the lowest dry weight (1.63 g m^{-2}). Among the herbicidal treatments, the activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant recorded less reduction in dry weight of *Medicago denticulate* (2.73 and 2.88 g m^{-2}, respectively) when it was applied at lower dose 14.38 *g a.i.* ha $^{-1}$. But, reduction in the dry weight of this weed was further improved with corresponding increase in application doses from 19.17 to 23.96 g *a.i*. ha^{-1} (2.48 and 1.97 g m^{-2}, respectively), being maximum in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i.* ha^{-1} (1.97g m^{-2}) and was found significantly superior to 14.38 g *a.i*. ha^{-1} and 19.17 g *a.i.* ha^{-1}. However, none of the herbicidal treatments excelled hand weeding twice which reduced the dry weight of *Medicago denticulata* to the maximum extent (1.63 g m^{-2}). Ready mixture application of post - emergence herbicide with surfactant gave better result as compared without surfactant. The application of single herbicide was proved less effective as compared to mixed application but the differences were significantly superior over the weedy check.

Table 4.9. Effect of different herbicidal treatments on dry weight of *Medicago denticulata* (g m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weed dry weight (30 DAA)		
			2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.66 (6.1)	2.79 (6.80)	2.73 (6.5)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.43 (5.0)	2.53 (5.40)	2.48 (5.2)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.02 (3.1)	1.92 (2.70)	1.97 (2.9)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.81 (6.9)	2.94 (7.70)	2.88 (7.3)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.70 (6.3)	2.68 (6.20)	2.69 (6.3)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.51 (5.3)	2.60 (5.80)	2.56 (5.6)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	3.00 (8.0)	3.02 (8.10)	3.01 (8.1)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	4.74 (21.6)	3.86 (14.00)	4.30 (17.8)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.75 (5.5)	2.84 (7.10)	2.80 (6.8)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1.80 (2.3)	1.83 (2.40)	1.82 (2.4)
T_{11}	Hand weeding twice	30 & 60 DAS	1.56 (1.4)	1.70 (1.90)	1.63 (1.7)
T_{12}	Control (weedy check)	-	5.41 (28.4)	5.69 (31.40)	5.55 (29.9)
SEm ±			**0.12**	**0.13**	**0.13**
CD (P=0.05)			**0.34**	**0.37**	**0.36**

Cichorium intybus

The dry weight of *Cichorium intybus* during both *Rabi* seasons (2016-17 and 2017-18) at 30 DAA was influenced by different weed control treatments are presented in Table 4.10 and graphically represented in Figure 4.10.

The different weed management practices significantly varied the dry weight of *Cichorium intybus* over weedy check during both the years of investigation. The highest weed dry weight was observed in unweeded control (4.12 g m^{-2}) whereas, hand weeding twice (30 and 60 DAS) recorded lowest mean dry weight (1.54 g m^{-2}) of *Cichorium intybus.* Among the herbicidal treatments, minimum dry matter of *Cichorium intybus* was observed by applying Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose 23.96 *g a.i.* ha $^{-1}$ (2.03 g m^{-2}) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant when applied at medium dose 19.14 *g a.i.* ha $^{-1}$ (2.41g m^{-2}) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant applied as higher dose 23.96 *g a.i.* ha $^{-1}$ (2.50 g m^{-2}) and proved significantly superior over all the herbicidal treatments. Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicide was less effective as compared to mixed application but the differences were significantly superior over unweeded control.

Table 4.10. Effect of different herbicidal treatments on dry weight of *Cichorium intybus* (g m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weed dry weight (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.61 (5.9)	2.88 (7.3)	2.75 (6.6)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.43 (4.9)	2.38 (4.7)	2.41 (4.8)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.10 (4.4)	1.96 (2.9)	2.03 (3.2)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.80 (6.8)	3.04 (8.3)	2.92 (7.4)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.64 (6.0)	2.67 (6.1)	2.66 (6.1)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.49 (5.2)	2.50 (5.3)	2.50 (5.3)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.85 (7.2)	3.01 (8.1)	2.93 (7.7)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	3.33 (10.0)	3.34 (10.2)	3.33 (10.1)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.57 (5.7)	2.80 (6.9)	2.69 (6.3)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1.87 (2.5)	1.77 (2.2)	1.82 (2.4)
T_{11}	Hand weeding twice	30 & 60 DAS	1.52 (1.3)	1.55 (1.4)	1.54 (1.4)
T_{12}	Control (weedy check)	-	3.82 (13.6)	4.41 (18.5)	4.12 (16.1)
SEm ±			**0.09**	**0.12**	**0.11**
CD (P=0.05)			**0.27**	**0.36**	**0.32**

Anagallis arvensis

The dry weight of *Anagallis arvensis* during both *Rabi* seasons (2016-17 and 2017-18) recorded at 30 DAA was influenced by different weed control treatments are cited in Table 4.11 and depicted in Figure 4.11.

The different weed management practices significantly reduced the dry weight of *Anagallis arvensis* over untreated control during both the years of investigation. It is obvious from the data that different weed control treatments had marked influence on the dry weight of *Anagallis arvensis* at 30 DAA. Data showed that weed control measures caused marked reduction on the dry weight of *Anagallis arvensis* as compared to weedy check. However, the dry weight of this weed was maximum (3.99 g m^{-2}) under weedy check where weeds were not controlled, but it was reduced identically with the post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lower dose 14.38 g *a.i.* ha^{-1} which caused reduction in the dry weight of *Anagallis arvensis* 2.41 and 2.52 g m^{-2}. But, reduction in the dry weight was further inched up to (2.13 and 1.73 g m^{-2}) with increase in the application doses with surfactant 19.17 and 23.96 g *a.i.* ha^{-1} being higher under plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i.* ha^{-1} (1.73 g m^{-2}) and proved significantly superior followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 19.17 g *a.i.* ha^{-1} (2.13 g m^{-2}) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant at 23.96 g *a.i.* ha^{-1} (2.23 g m^{-2}). However, hand weeding twice ranked first among all the weed control treatments in curbing the dry weight of *Anagallis arvensis* to the tune of (1.43 g m^{-2}). Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the unweeded control (weedy check).

Table 4.11. Effect of different herbicidal treatments on dry weight of *Anagallis arvensis* (g m^{-2}) in wheat at 30 days after application

Treatment		**Dose (g *a.i.* ha^{-1})**	**Weed dry weight (30 DAA)**		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.21 (3.8)	2.60 (5.8)	2.41 (4.8)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	1.94 (2.8)	2.31 (4.3)	2.13 (3.6)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	1.63 (1.7)	1.82 (2.3)	1.73 (2.0)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.29 (4.2)	2.75 (6.6)	2.52 (5.4)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.14 (3.6)	2.60 (5.8)	2.37 (4.7)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	1.98 (2.9)	2.48 (5.1)	2.23 (4.0)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.46 (5.0)	3.22 (9.4)	2.84 (7.2)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	2.65 (6.0)	3.79 (13.4)	3.22 (9.7)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.21 (3.9)	2.95 (7.7)	2.58 (5.8)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1.58 (1.5)	1.61 (1.6)	1.60 (1.6)
T_{11}	Hand weeding twice	30 & 60 DAS	1.39 (1.0)	1.47 (1.2)	1.43 (1.1)
T_{12}	Control (weedy check)	-	3.30 (9.9)	4.67 (20.8)	3.99 (15.4)
SEm ±			**0.05**	**0.10**	**0.08**
CD (P=0.05)			**0.13**	**0.29**	**0.21**

Chenopodium album

The dry weight (g m-^{2}) of *Chenopodium album* during both *Rabi* seasons (2016-17 and 2017-18) for 30 DAA was influenced by different weed control treatments are shown in Table 4.12 and graphically represented in Figure 4.12.

Results indicated that different weed control measures caused significant reduction on the dry weight of *Chenopodium album* (g m^{-2}) as compared to weedy check during both the years of investigation. The highest weed dry matter was noted in unweeded control (4.84 g m^{-2}) whereas; hand weeding twice (30 and 60 DAS) recorded lowest mean dry matter (1.55 g m^{-2}) of *Chenopodium album.* Among the herbicidal treatments, the activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant which caused reduction in dry weight of *Chenopodium album (*2.47 and 2.68 g m^{-2}) when it was applied at lower dose 14.38 *g a.i.* ha $^{-1}$ over the weedy check, but it was further increased appreciably with corresponding increase in doses being maximum when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha $^{-1}$ (1.81 g m^{-2}) and found significantly superior over the other treatments. followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha $^{-1}$ (2.31 g m^{-2}) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 23.96 *g a.i.* ha $^{-1}$ (2.39 g m^{-2}). Ready mixture application of post emergence herbicide with surfactant gave better result as compared to without surfactant. The application of single herbicide was less effective as compared to mixed application but the differences were significantly superior over the weedy check.

Table 4.12. Effect of different herbicidal treatments on dry weight of *Chenopodium album* (g m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weed dry weight (30 DAA)		
			2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.34 (4.4)	2.59 (5.7)	2.47 (5.1)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.15 (3.6)	2.46 (5.1)	2.31 (4.4)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	1.67 (1.8)	1.95 (2.8)	1.81 (2.3)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.42 (4.9)	2.93 (7.6)	2.68 (6.3)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.30 (4.3)	2.70 (6.3)	2.50 (5.3)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.19 (3.8)	2.59 (5.7)	2.39 (4.8)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.42 (4.9)	2.89 (7.4)	2.66 (6.2)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	3.11 (8.7)	3.67 (12.5)	3.39 (10.6)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.26 (4.1)	2.53 (5.4)	2.40 (4.8)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1.60 (1.6)	1.72 (2.0)	1.66 (1.8)
T_{11}	Hand weeding twice	30 & 60 DAS	1.46 (1.1)	1.63 (1.7)	1.55 (1.4)
T_{12}	Control (weedy check)	-	4.04 (15.4)	5.64 (31.0)	4.84 (23.2)
SEm ±			**0.08**	**0.12**	**0.10**
CD (P=0.05)			**0.23**	**0.37**	**0.30**

Medicago truncatula

The dry weight of *Medicago truncatula* during both the *Rabi* seasons (2016-17 and 2017-18) at 30 DAA influenced by different weed control practices are presented in Table 4.13 and depicted in Figure 4.13. The different weed management practices significantly reduced the dry weight of *Medicago truncatula* over untreated control during both the year of investigation.

It is obvious from the data that all the herbicidal treatments including hand weeding twice had significantly lowered the dry weight of *Medicago truncatula* at 30 DAA as compared to weedy check. The dry weight of this weed was maximum (5.84 g m^{-2}) under weedy check due to uninterrupted growth of weeds during critical period of crop-weed competition. Among the herbicidal treatments, the activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant was recorded some reduction in dry weight of *Medicago truncatula,* when it was applied at lower dose 14.38 g *a.i*. ha^{-1} and it caused reduction in the dry weight over weedy check (3.10 and 3.41 g m^{-2}). But reduction in the dry weight of this weed was improved when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at higher doses 19.17 and 23.96 *g a.i.* ha $^{-1}$ being maximum in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 *g a.i.* ha $^{-1}$ (2.30 g m^{-2}) and was found significantly superior over rest of treatments, However, hand weeding twice stood first (1.70 g m^{-2}) in curbing the dry weight of *Medicago truncatula* among all the weed control treatments. Ready mixture application of post - emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the untreated plots.

Table 4.13. Effect of different herbicidal treatments on dry weight of *Medicago truncatula* (g m^{-2}) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	Weed dry weight (30 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	3.13 (8.8)	3.07 (8.4)	3.10 (8.6)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.95 (7.8)	2.90 (7.4)	2.93 (7.6)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.26 (4.1)	2.33 (4.4)	2.30 (4.3)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	3.43 (10.8)	3.38 (10.4)	3.41 (10.6)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	3.21 (9.3)	3.15 (9.0)	3.18 (9.2)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	3.06 (8.4)	3.01 (8.1)	3.04 (8.3)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	3.52 (11.4)	3.47 (11.0)	3.50 (11.2)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	4.42 (18.6)	4.83 (22.4)	4.63 (20.5)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	3.44 (10.8)	3.39 (10.5)	3.42 (10.7)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1.98 (2.9)	1.97 (2.9)	1.98 (2.9)
T_{11}	Hand weeding twice	30 & 60 DAS	1.72 (2.0)	1.68 (1.8)	1.70 (1.9)
T_{12}	Control (weedy check)	-	6.01 (35.2)	5.67 (31.2)	5.84 (33.2)
SEm ±			**0.10**	**0.11**	**0.11**
CD (P=0.05)			**0.29**	**0.33**	**0.31**

4.1.4 Weed control efficiency of monocot weeds

The mean data on weed control efficiency in respect of monocot weed *i.e., Cyperus iria* of two *Rabi* seasons (2016-17 and 2017-18) at 30 DAA as influenced by different weed control treatments are given in Table 4.14 and depicted through Figure 4.14.

The data showed that different weed control measures had noticeable influence on efficiency to control the monocot weed at 30 DAA. Post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lower dose 14.38 g *a.i* ha^{-1} caused appreciable reduction (59.3 and 53.8 %) in dry weight of *Cyperus iria* which was further increased with corresponding increase in dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant (from 14.38 to 23.95 g *a.i*. ha^{-1}) from 86.95 to 91.79 per cent and 86.20 to 90.46 per cent, respectively. However, hand weeding twice excelled to all the herbicidal treatments as it attained 92.97, per cent efficiency to control *Cyperus iria*.

4.1.5 Weed control efficiency of dicot weeds

The mean data on weed control efficiency in respect of dicot weeds *viz., Cichorium intybus, Anagallis arvensis*, *Medicago denticulata*, *Chenopodium album* and *Medicago truncatula* for two *Rabi* seasons (2016-17 and 2017-118) at 30 DAA under different weed control treatments are presented in Table 4.14 and depicted through Figure 4.14.

Data pertaining to weed control efficiency revealed that the activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant was lower against broad leaf weeds when it was applied at lowest dose 14.38 g *a.i* ha^{-1} hence it attained lowest weed control efficiency. But, weed control efficiency against the *Cichorium intybus, Anagallis arvensis*, *Medicago denticulata*, *Chenopodium album* and *Medicago truncatula* was slightly inched up to 80.4, 87.0, 90.3, 90.1 and 87.2 % respectively, with increase in the application doses 23.95 g *a.i.* ha^{-1} . Followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant applied at medium dose 19.17 g *a.i*. ha^{-1} 70.1, 76.9, 82.6, 81.3, 90.1 and 77.1 % respectively. However, none of the herbicidal treatments surpassed hand weeding twice maximum extent weed control efficiency (91.6, 93.2, 94.5, 94.0 and 94.3 %, respectively) and found superior to all the herbicidal treatments.

Table 4.14. Effect of different herbicidal treatments on weed control efficiency (%) in wheat at 30 days after application

Treatment		Dose (g *a.i.* ha^{-1})	*Cyperus iria*	*Medicago denticulata*	*Cichorium intybus*	*Anagallis arvensis*	*Chenopodium album*	*Medicago truncatula*
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	59.3	78.4	58.9	68.7	78.2	74.1
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	67.7	82.6	70.1	76.9	81.3	77.1
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	76.1	90.3	80.4	87.0	90.1	87.2
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	53.8	75.6	53.0	64.8	73.1	68.1
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	62.2	79.1	62.3	69.4	77.2	72.4
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	66.4	81.4	67.3	73.9	79.5	75.2
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	53.3	73.1	52.3	53.1	73.5	66.3
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	51.5	40.5	37.1	36.8	54.3	38.3
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	59.9	77.3	60.7	62.2	79.5	67.9
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	82.4	92.1	85.4	89.9	92.2	91.3
T_{11}	Hand weeding twice	30 & 60 DAS	86.8	94.5	91.6	93.2	94.0	94.3
T_{12}	Control (weedy check)	-	0.0	0.0	0.0	0.0	0.0	0.0

4.2 STUDY ON CROP

Data on growth parameters of wheat as affected by weed control practices were recorded at 30, 60, 90 DAS and harvest. Data pertaining to growth parameters *viz.,* plant height, number of leaves plant^{-1}, number of tillers, LAI, crop dry weight of 60 DAS, chlorophyll content at 60 DAS, crop growth rate, relative growth rate, 30-60 DAS, yield attributing traits, yield, nutrient uptake recorded at harvest and effect of herbicidal treatments on succeeding soybean crop are described below under the following heads :-

4.2.1 Plant population

It is evident from the data presented in Table 4.15 and graphically represented in Figure 4.15 that plant population (m^{-2}) of wheat was almost similar during both the years of experimentation. The plant population varied under different treatments from 198.1 to 203.6 m^{-2} during 2016-17 and 201.0 to 2 07.0 m^{-2} in 2017-18. Application of post emergence herbicide did not cause any variation on plant population at 15 DAS during both the years because weed control practices were not applied at 15 DAS.

At harvest, the plant population of wheat was statistically similar under all the weed control treatments and did not have any influence on plant population of wheat as the post emergence application of herbicides Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant did not cause any phytotoxicity and mortality of crop plants and therefore plant population was alike under all the weed control treatments including weedy check during both the years, respectively. However, yellowing and chlorosis in crop plants was observed in case of higher dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 47.4 g *a.i*. ha^{-1} after 10 days of application and later the plants were recovered and there was no mortality of crop plants.

Table 4.15. Effect of different herbicidal treatments on plant population of wheat

Treatment		Dose (g *a.i.* ha^{-1})	15 DAS			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	198.9	203.1	201.0	196.8	196.3	196.6
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	199.9	207.0	203.4	198.1	197.0	197.6
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	202.0	205.2	203.6	198.9	197.8	198.3
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	196.9	201.3	199.1	195.2	195.7	195.4
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	198.7	202.2	200.4	194.9	196.3	195.6
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	196.4	201.3	198.9	188.8	196.3	192.6
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	197.6	204.7	201.1	197.8	196.4	197.1
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	200.9	205.9	203.4	199.8	196.9	198.3
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	197.4	201.0	199.2	196.4	197.1	196.8
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	196.9	201.1	199.0	195.8	196.7	196.2
T_{11}	Hand weeding twice	30 & 60 DAS	195.1	201.3	198.2	194.7	197.7	196.2
T_{12}	Control (weedy check)		198.7	201.8	200.2	197.0	197.0	197.0
SEm ±			**2.42**	**2.6**	**2.5**	**2.81**	**0.41**	**1.61**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.2.2 Plant height

Plant height a measure of growth was recorded periodically at an interval of 30 days starting from 30th day up to harvest. The data related to plant height at different time interval of crop are given in Table 4.16 and graphically represented in Figure 4.16 indicate that the plant height was found to be influenced significantly due to different weed control practices at different interval except 30 day stage. A perusal of the data revealed that the plant attained only a nominal height within the first 30 days. Thereafter, there was a steady rise in the plant height which continued till harvest. However, the rate of increase in plant height was quite slow after 90 days of sowing.

The different weed management practices significantly influenced the plant height of wheat at 60 DAS over weedy check during both the year of investigation. The maximum plant height was recorded under hand weeding twice 30 and 60 DAS (63.7 cm) whereas, the minimum plant height was recorded under weedy check (52.0 cm) where weeds were not control. Among the herbicidal treatments, slightly increased plant height was observed when the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant 14.38 g *a.i.* ha^{-1} at lower dose (58.2 and 56.1 cm, respectively), which was further increased to the tune of 62.3 cm when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant applied at higher dose 23.96 *g a.i.* ha^{-1}. The plant height was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at medium dose 19.17 *g a.i.* ha^{-1}. However, none of the herbicidal treatment excelled to hand weeding twice which attained the maximum (63.7 cm) plant height of wheat and proved superior to all the herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

Table 4.16. Effect of different herbicidal treatments on plant height (cm) of wheat at 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Plant height (60 DAS)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	58.4	58.0	58.2
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	59.7	59.5	59.6
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	62.5	62.2	62.3
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	56.2	56.0	56.1
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	58.5	58.3	58.4
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	58.8	58.6	58.7
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	57.9	57.8	57.8
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	58.6	58.5	58.5
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	57.4	57.2	57.3
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	55.8	56.3	56.0
T_{11}	Hand weeding twice	30 & 60 DAS	63.8	63.6	63.7
T_{12}	Control (weedy check)	-	52.2	51.9	52.0
SEm ±			**0.96**	**1.00**	**0.98**
CD (P=0.05)			**2.83**	**2.96**	**2.90**

4.2.3 Visual phytotoxicity scoring: the data of the treatments on visual phytotoxicity are given below

The mean data on visual phytotoxicity scoring of two *Rabi* seasons (2016-17 and 2017-18) at 1, 3, 5, 7 and 10 DAA as influenced by different weed control treatments are given in Table 4.17.

The different weed management practices significantly influenced phytotoxici the wheat at 1, 3, 5, 7 and 10 DAA DAS during both the year of investigation.

Table 4.17. Effect of weed control treatment on visual phytotoxicity scoring in wheat at different time intervals

Treatment		Dose (g *a.i.* ha^{-1})	Visual rating score (DAA)				
			1	**3**	**5**	**7**	**10**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	0	0	0	0	0
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	0	0	0	0	0
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	0	0	0	0	0
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	0	0	0	0	0
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	0	0	0	0	0
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	0	0	0	0	0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	0	0	0	0	0
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	0	0	0	0	0
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	0	0	0	0	0
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	3	3	2	1	1
T_{11}	Hand weeding twice	30 & 60 DAS	0	0	0	0	0
T_{12}	Control (weedy check)	-	0	0	0	0	0

1 day after application

A perusal of visual phytotoxicity scoring revealed that at 1DAA Halauxifen – methyl + Pyroxsuma with surfactant 47.93 g *a.i*. ha^{-1} gave setback to wheat crop by causing moderate but persistent injury to wheat plants putting the plants under doubtful recovery zone.

3 day after application

A perusal of visual phytotoxicity scoring revealed that at 1DAA Halauxifen – methyl + Pyroxsuma with surfactant 47.93 g *a.i*. ha^{-1} gave setback to wheat crop by causing moderate but persistent injury to wheat plants putting the plants under doubtful recovery zone.

5, 7 and 10 day after application

With the progression of time, the phytotoxicity caused by this herbicide was reversed. The visual scoring 5, 7 and 10 DAA manifested some stunting of wheat plants under the effect of Halauxifen – methyl + Pyroxsuma with surfactant 47.93 g *a.i.* ha^{-1} and showed slight injury or discoloration only.

4.2.4 Number of tillers (meter^{-2})

The data on number of tillers per (meter^{-1} row length) was presented in Table 4.18 and depicted in Fig. 4.17 showed that increasing trend in number of tillers per (meter^{-1} row length) was observed from 30 DAS to 60 DAS. Afterwards, the tillering in wheat was declined. The different weed management practices significantly influenced the number of tillers (meter^{-1} row length) of wheat at 60 DAS over untreated control during both the years of investigation.

It is evident from the data that different weed control treatments caused significant variation on the number of tillers (meter^{-1} row length) at 60 DAS. Weedy check had minimum (260.2 meter^{-1} row length) number of tillers. But number of tillers increased appreciably when control measures were adopted in different plots.

Application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at lower dose 14.38 *g a.i.* ha^{-1} caused remarkable increase in number of tillers(273.7 and 268.7 meter^{-1} row length, respectively) in wheat over weedy check, which was further increased with corresponding increase in Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant application dose from 19.17 to 23.96 *g a.i.* ha $^{-1}$ being higher when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha^{-1} (285.3 meter^{-1} row length) and proved significantly superior over other herbicidal treatments followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 19.17 *g a.i.* ha^{-1} (280.7 meter^{-1} row length). However, hand weeded plots were produced maximum number of tillers (286.5 meter^{-1} row length). Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicide was less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

Table 4.18. Effect of different herbicidal treatments on tillers meter^{-2} of wheat at 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Tillers meter^{-1} row length (60 DAS)		
			2017	**2018**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	274.7	272.7	273.7
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	281.7	279.7	280.7
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	286.3	284.3	285.3
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	269.7	267.7	268.7
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	272.7	270.3	271.5
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	274.7	272.3	273.5
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	269.0	267.0	268.0
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	270.0	268.0	269.0
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	272.0	270.0	271.0
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	265.3	263.3	264.3
T_{11}	Hand weeding twice	30 & 60 DAS	287.7	285.3	286.5
T_{12}	Control (weedy check)	-	261.7	258.7	260.2
SEm ±			**0.98**	**1.07**	**1.03**
CD (P=0.05)			**2.89**	**3.15**	**3.02**

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4.2.5 Crop dry matter production (g m^{-2})

The crop dry matter production (g m^{-2}) of wheat was recorded from each treatment at different time intervals and the mean data after statistical analysis are depicted in Tables 4.19 and exhibited through Fig. 4.18 The results revealed that the crop dry matter production (g m^{-2}) in general, increased with the increase of plant growth from 30 day stage up to the harvest.

The different weed management practices significantly influenced the crop dry matter production (g m^{-2}) of wheat at 60 DAS over weedy check during both the years of investigation. The higher crop dry matter production was recorded under hand weeding twice 30 and 60 DAS (1017.4 g m^{-2}) whereas, the lower dry matter production was recorded under weedy check (848.9 g m^{-2}) where weeds were not controlled. Among the herbicidal treatments, crop biomass was increased markedly in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant even at the lower dose 14.38 *g a.i.* ha^{-1} (925.8 and 892.7 g m^{-2}). However, the crop biomass was further increased with the increase in dose being higher (998.2 g m^{-2}) when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha^{-1} and proved significantly superior over lower dose 14.38 and 19.17 g *a.i.* ha^{-1} (925.8 and 948.5 g m^{-2}, respectively). Ready mixture application of post emergence herbicide with surfactant gave better results as compared to application without surfactant. The applications of single herbicides were less effective as compared to mixed application but the differences were significantly superior over the weedy check.

Table 4.19. Effect of different herbicidal treatments on crop dry matter production (g m^{-2}) of wheat at 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Crop dry matter production (60 DAS)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	920.2	931.5	925.8
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	943.5	953.5	948.5
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	996.4	1000.0	998.2
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	901.3	884.1	892.7
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	924.1	921.0	922.5
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	942.0	934.5	938.3
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	866.2	869.9	868.0
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	869.7	878.5	874.1
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	878.4	864.1	871.3
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	856.3	856.4	856.4
T_{11}	Hand weeding twice	30 & 60 DAS	1033.5	1001.2	1017.4
T_{12}	Control (weedy check)	-	845.6	852.2	848.9
SEm ±			**9.27**	**12.66**	**10.97**
CD (P=0.05)			**27.36**	**37.37**	**32.37**

4.2.6 Number of leaves plant^{-1}

The mean data leaves plant^{-1} of two *Rabi* seasons (2016-17 and 2017-18) at 60 DAS as influenced by different weed control treatments.

The number of leaves plant^{-1} was found to be increased with the advancement in the age of crop plant up to different stage and it remained constant up to 90th day stage and thereafter it decreased considerably up to harvest under the effect of all the weed control treatments including weedy check.

The data pertaining to the number of leaves plant^{-1} recorded at different stages of crop growth were statistically analyzed (Appendix-V) and the overall effects of different weed control treatments were included in Table 4.20 and exhibited through Fig. 4.19 the results revealed that the number of leaves per plant was found non-significant by the various weed control treatments at 60 days after sowing.

Table 4.20. Effect of different herbicidal treatments on leaves plant^{-1} of wheat at 60 Days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	number of leaves plant^{-1} (60 DAS)		
			2017	**2018**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	17.5	18.2	17.9
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	17.5	17.9	17.7
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	17.6	18.0	17.8
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	17.3	17.4	17.4
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	17.2	17.8	17.5
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	17.7	18.4	18.0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	17.3	18.0	17.6
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	17.4	17.6	17.5
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	17.5	18.0	17.8
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	17.4	17.9	17.7
T_{11}	Hand weeding twice	30 & 60 DAS	17.7	18.0	17.9
T_{12}	Control (weedy check)	-	17.2	17.5	17.3
SEm ±			0.19	0.52	0.36
CD (P=0.05)			NS	NS	NS

4.2.7 Chlorophyll content

The mean data on chlorophyll content in wheat plant of two *Rabi* season (2016-17 and 2017-18) recorded at 60 DAS under different weed control treatments are cited in Table 4.21 and graphically represented in Figure 4.20.

Weed control treatments had marked influence on chlorophyll content of wheat at 60 DAS. Chlorophyll content was minimum (49.66 %) in the plots receiving higher dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 47.93 g *a.i.* ha^{-1} followed by weedy check (52.75 %) where weeds were not controlled by any means, suggesting that post emergence application Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 47.93 g *a.i*. ha^{-1} had chlorosis effect on wheat crop which resulted in minimum chlorophyll content of wheat, whereas the chlorophyll content was reduced in weedy check plots due to sever competition effect by weeds. However, the post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose and unweeded check were statistically similar in producing the chlorophyll content as the difference among them did not reach to the level of significance. But the plots receiving application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i.* ha^{-1} were registered higher chlorophyll content (56.13 %) being statistically similar to its lower dose 19.17 g *a.i.* ha^{-1} and proved significantly superior over higher dose 47.93 g *a.i.* ha^{-1} and unweeded check at 60 DAS. However, none of the herbicidal treatments excelled to hand weeding once which attained the maximum (56.23 %) chlorophyll content of wheat and was found superior to all the herbicidal treatments.

Table 4.21. Effect of different herbicidal treatments on chlorophyll content of wheat at 60 Days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	chlorophyll content (60 DAS)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	55.3	54.6	54.97
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	55.4	55.5	55.45
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	56.1	56.2	56.13
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	55.3	55.2	55.24
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	55.1	55.7	55.42
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	55.8	55.9	55.84
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	55.0	54.9	54.95
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	55.2	54.8	55.01
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	55.6	56.0	55.82
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	50.0	49.3	49.66
T_{11}	Hand weeding twice	30 & 60 DAS	56.2	56.3	56.23
T_{12}	Control (weedy check)	-	53.5	52.0	52.75
SEm ±			**0.35**	**0.64**	**0.50**
CD (P=0.05)			**1.02**	**1.90**	**1.46**

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

The CGR of wheat was computed under every treatment at different growth stages and the mean values, after statistical analysis is presented in Table 4.22 and exhibited through Fig. 4.21.The scrutiny of data in Table 4.22 revealed that in general, CGR increased with the increase in plant growth from 30 DAS to 90 DAS stage. Thereafter, it tended to decline up to maturity under the various treatments. The different weed management practices significantly influenced the crop growth rate of wheat at 30 - 60 DAS over weedy check during both the years of investigation. The higher crop growth was recorded under hand weeding twice 30 and 60 DAS (28.8 g m^{-2} day^{-1}) whereas, the lower crop growth rate was recorded under weedy check (23.9 g m^{-2} day^{-1}). Among the herbicidal treatments, maximum crop growth rate was observed when the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose 23.96 *g a.i.* ha^{-1} (27.8 g m^{-2} day^{-1}). The crop growth rate decreased when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant applied at lower dose 14.38 and 19.17 *g a.i.* ha^{-1} (26.1 and 26.7 g m^{-2} day^{-1}). The higher dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 *g a.i.* ha $^{-1}$ proved significantly superior over all the herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better results as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significant over the weedy check.

Table 4.22. Effect of different herbicidal treatments on CGR (g m^{-2} day^{-1}) of wheat at 30 – 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Crop growth rate (30 – 60 DAS)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	26.0	26.23	26.1
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	26.6	26.79	26.7
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	27.8	27.83	27.8
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	25.3	25.13	25.2
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	25.7	26.0	25.9
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	26.4	26.73	26.6
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	24.6	24.63	24.6
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	24.3	24.38	24.3
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	25.0	24.32	24.6
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	24.3	24.2	24.2
T_{11}	Hand weeding twice	30 & 60 DAS	28.8	28.87	28.8
T_{12}	Control (weedy check)	-	23.9	23.95	23.9
SEm ±			**0.25**	**0.27**	**0.26**
CD (P=0.05)			**0.74**	**0.79**	**0.77**

4.2.9 Relative growth rate (g g^{-1} day^{-1})

The RGR of wheat was calculated under each treatment at different growth intervals and the mean values, after statistical analysis, are highlighted in Table 4.23 and illustrated through Fig .4.22. The perusal of data in Table 4.23 indicated that the RGR, in general, increased with the increase in plant growth from 30 DAS to 60 DAS. Thereafter, the RGR tended to decrease slowly up to 90 DAS and then very fast on the crop maturity in the various treatments. The different weed management practices significantly influenced the crop growth rate of wheat at 30 - 60 DAS over weedy check during both the year of investigation. The higher crop growth was recorded under hand weeding twice 30 and 60 DAS (0.1051 g g^{-2} day^{-1}) whereas, the lower crop growth rate was recorded under weedy check (0.0964 g g^{-1} day^{-1}). Among the herbicidal treatments, maximum crop growth rate was observed with the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose 23.96 *g a.i.* ha^{-1} (0.1017 g g^{-1} day^{-1}) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha^{-1} (0.0994 g g^{-1} day^{-1}). Proved significantly superior over all the herbicidal treatments. Ready mixture application of post - emergence herbicide with surfactant gave better results as compared to application without surfactant. The application of single herbicide was less effective as compared to mixed application but the differences were significant over the unweeded control.

Table 4.23. Effect of different herbicidal treatments on RGR (g g^{-1} day^{-1}) of wheat at 30 – 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Relative growth rate (30 – 60 DAS)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	0.09854	0.09631	0.0974
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	0.10116	0.09771	0.0994
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	0.10209	0.10133	0.1017
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	0.09936	0.0993	0.0993
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	0.09971	0.09677	0.0982
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	0.10048	0.09882	0.0997
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	0.0985	0.09654	0.0975
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	0.09639	0.09426	0.0953
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	0.096	0.09353	0.0948
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	0.09685	0.09328	0.0951
T_{11}	Hand weeding twice	30 & 60 DAS	0.10576	0.10445	0.1051
T_{12}	Control (weedy check)	-	0.09727	0.0955	0.0964
SEm ±			**0.001**	**0.001**	**0.001**
CD (P=0.05)			**0.003**	**0.004**	**0.004**

4.2.10 Leaf area (cm^{-2})

The leaf area (LA) values were computed at different growth intervals of the crop and summarized in Table 4.24 and illustrated in Fig. 4.23. The LA of wheat was increased with the progress of crop age up to 60 DAS and declined thereafter. The different weed management practices significantly influenced the leaf area of wheat at 60 DAS over weedy check during both the years of investigation. The higher leaf area was recorded under hand weeding twice 30 and 60 DAS (275 cm) whereas, the lower leaf area was recorded under weedy check (240.9 cm)*.* Among the herbicidal treatments, maximum leaf area was observed with the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 *g a.i.* ha $^{-1}$ (272.1 cm) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha $^{-1}$ (262.9) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 23.96 *g a.i.* ha $^{-1}$ (259.8 cm) and proved significantly superior over all the herbicidal treatments. Ready mixture application of above post emergence herbicide with surfactant gave better results as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significant over the unweeded control.

Table 4.24. Effect of different herbicidal treatments on leaf area (cm^{-2}) of wheat at 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Leaf area (60 DAA)		
			2016-17	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	256.4	256.2	256.3
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	262.1	263.7	262.9
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	271.8	272.3	272.1
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	250.6	249.2	249.9
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	254.9	254.1	254.5
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	260.5	259.1	259.8
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	249.4	247.2	248.3
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	249.3	246.9	248.1
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	251.0	250.8	250.9
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	250.1	248.5	249.3
T_{11}	Hand weeding twice	30 & 60 DAS	274.7	275.2	275.0
T_{12}	Control (weedy check)	-	238.0	243.7	240.9
SEm ±			**1.1**	**0.9**	**1.0**
CD (P=0.05)			**3.1**	**2.6**	**2.9**

4.2.11 Leaf area index (LAI)

The LAI values were computed at different growth stages of the crop and summarized in Table 4.25 and illustrated in Fig. 4.24. The LAI of wheat was increased with the progress of crop age up to 60 DAS and declined thereafter. The different weed management practices significantly influenced the leaf area index of wheat at 60 DAS over weedy check during both the year of investigation. The higher leaf area index was recorded under hand weeding twice (30 and 60 DAS) (4.89) whereas, the lower leaf area index was recorded under weedy check (4.28). But leaf area index increased appreciably when control measures were adopted in different plots. Application Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lower dose 14.38 *g a.i.* ha^{-1} caused the remarkable increase in leaf area index (4.56 and 4.44) in wheat over weedy check (4.28), which was further increased with corresponding increase in dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant application dose from 19.17 to 23.96 *g a.i.* ha^{-1} being higher when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha^{-1} (4.84) and proved significantly superior over other herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

Table 4.25. Effect of different herbicidal treatments on leaf area index of wheat at 60 days after sowing

Treatment		Dose (g *a.i.* ha^{-1})	Leaf area index (60 DAA)		
			2016-17	**2017-18**	**Mean**
T$_1$	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	4.56	4.56	4.56
T$_2$	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	4.66	4.69	4.68
T$_3$	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	4.83	4.84	4.84
T$_4$	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	4.45	4.43	4.44
T$_5$	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	4.53	4.52	4.53
T$_6$	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	4.63	4.61	4.62
T$_7$	Pyroxsulam 4.5% **with surfactant**	18.75	4.43	4.39	4.41
T$_8$	Halauxifen-methyl 10.42% **with surfactant**	5.21	4.43	4.39	4.41
T$_9$	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	4.46	4.46	4.46
T$_{10}$	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	4.45	4.42	4.44
T$_{11}$	Hand weeding twice	30 & 60 DAS	4.88	4.89	4.89
T$_{12}$	Control (weedy check)	-	4.23	4.33	4.28
SEm ±			**0.07**	**0.07**	**0.07**
CD (P=0.05)			**0.02**	**0.02**	**0.02**

4.2.12 Effective tillers (m^{-2})

An examination of data revealed that Table 4.26 and illustrated through Fig .4.25 different weed control treatments significantly increased the effective tillers over weedy check during both the year of experimentation. Hand weeding twice recorded the highest mean effective tillers (302.5 m^{-2}) and lowest mean effective tillers were recorded under weedy check (252.5 m^{-2}). But number of effective tillers increased identically when control measures were adopted in different plots. Application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lowest dose 14.38 *g a.i.* ha $^{-1}$ (284.8 and 279.2 m^{-2}) caused the remarkable increase in number of effective tillers of wheat, which was further increased with corresponding increase in doses of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant from 19.17 to 23.96 *g a.i.* ha $^{-1}$ being higher when it was applied at 23.96 *g a.i.* ha $^{-1}$ (296.8 m^{-2}) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha $^{-1}$ (289.0 m^{-2}). Higher dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 *g a.i.* ha $^{-1}$ was found superior over other herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the unweeded control. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application single herbicide was less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

Table 4.26. Effect of different herbicide treatments on yield attributes of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Effective tillers (m^{-2})	Length of ear head (cm)	Grains ear $head^{-1}$	Test weight (g)
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	284.8	9.0	49.4	43.6
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	289.0	9.2	50.2	44.3
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	296.8	9.4	50.9	45.2
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	279.2	8.7	48.8	43.3
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	285.0	8.8	49.8	43.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	291.9	9.0	50.1	44.0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	273.2	8.7	47.9	43.2
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	269.7	8.7	48.0	43.1
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	274.4	8.8	46.7	43.2
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	265.7	8.3	47.3	43.1
T_{11}	Hand weeding twice	30 & 60 DAS	302.9	9.6	51.1	45.3
T_{12}	Control (weedy check)	-	252.5	7.8	45.4	42.5
SEm ±			**3.62**	**0.08**	**0.28**	**0.26**
CD (P=0.05)			**10.68**	**0.24**	**0.84**	**0.76**

4.2.13 Length of ear head (cm)

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to length of ear head (cm) as influenced by different weed control treatments are presented in Table 4.26 and depicted through Figure 4.25.

The different weed management practices significantly influenced the length of ear head over weedy check during both the year of investigation. The higher length of ear head was recorded under hand weeding twice 30 and 60 DAS (9.6 cm) whereas, the lower length of ear head was recorded under weedy check (7.8 cm) which was increased when weed control measures were adopted. Post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at all doses 14.38, 19.17 and 23.96 g *a.i*. ha^{-1} (9.0, 9.2 and 9.4 cm respectively) was statistically similar in terms of length of ear head and proved significantly superior over unweeded check (7.8 cm), except the lowest dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 14.38 g *a.i.* ha^{-1} (9.0). However, hand weeded plots had maximum ear head length (9.6 cm) being at par to Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} and proved superior to rest of treatment including weedy check. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

4.2.14 Grain ear head^{-1}

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to grain ear head^{-1} as influenced by different weed control treatments are presented in Table 4.26 and depicted through Figure 4.25.

It is clearly inferred from data that the number of grains was significantly influenced by different weed control treatments during both the year of experimental. The minimum number of mean grains ear head^{-1} (45.4) was produced when the crop was subjected to allow weed infestation (weedy check). This number was increased significantly when weed control was employed by various means. Maximum grain ear head^{-1} (51.1) was produced under hand weeding twice. Among the herbicidal treatment maximum number of grains ear head^{-1} mean was recorded under application of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant 23.96 g *a.i.* ha^{-1} (50.9) which was closely at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant g *a.i.* 19.17 ha^{-1} (50.2) and at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25% without surfactant g *a.i.* 23.96 ha^{-1} (49.8) and proved significantly superior over all the herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the weedy check.

4.2.15 Test weight (g)

The mean data of two Rabi season (2016-17 and 2017-18) of test weight of wheat as influenced by different weed control treatments was showned in Table 4.26 and graphically represented in Figure 4.25.

The higher test weight (45.3 g) was recorded under hand weeding twice (30 and 60 DAS) whereas, the lower test weight was recorded under weedy check (42.5 g). But test weight increased appreciably when control measures were adopted in different pots. Application of halauxifen –methyl 6.95 %+ pyroxsulam 25 % with and without surfactant at lower dose 14.38 g *a.i.* ha^{-1} caused remarkable increase in test weight (43.6 and 43.3 g, respectively) in wheat over weedy check (42.5 g), which was further increased with corresponding increase in halauxifen –methyl 6.95 % + pyroxsulam 25 % with surfactant application dose from 19.96 to 23.96 g *a.i*. ha^{-1} being higher when halauxifen –methyl 6.95 % + Pyroxsulam 25 % with surfactant application dose from 23.96 g *a.i.* ha^{-1} (45.2 g) and proved significantly superior over other herbicidal treatment

4.2.16 Biological yield (kg ha^{-1})

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to biological yield (kg ha^{-1}) as influenced by different weed control treatments are presented in Table 4.27.

A reference to data indicates that weed control measures brought about significant variation in biological yield of wheat crop during both the year of investigation. The highest mean biological yield of wheat was recorded under hand weeding twice (11565 kg ha^{-1}) and lowest mean biological yield was recorded under weedy check (8103 kg ha^{-1}). But biological yield increased appreciably when control measures were adopted in different plots. Application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at the lowest dose 14.38 *g a.i.* ha^{-1} caused the remarkable increase in biological yield (10977 and 10765 kg ha^{-1}, respectively) in wheat over weedy check (8103 kg ha^{-1}), which was further increased with corresponding increase in Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant application dose from 19.17 to 23.96 *g a.i.* ha $^{-1}$ being higher when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha^{-1} (11380 kg ha^{-1}) and proved significantly superior over other herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

4.2.17 Grain yield (kg ha^{-1})

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to grain yield (kg ha^{-1}) as influenced by different weed control treatments is presented in Table 4.27 and depicted through Figure 4.26.

Application of different weed control treatments brought about marked increase in the grain yield of wheat over weedy check during both the years of experimentation. Hand weeding twice (30 & 60 DAS) recorded highest mean grain yield (4919 kg ha^{-1}) whereas weedy check accounted for minimum value (3169 kg ha^{-1}) where weeds were allowed to grow throughout crop season. Further insight of data explicate that collective application of herbicides as ready mixture gave significantly higher grain yield of wheat over singly applied herbicides. Among the herbicidal treatments, grain yield was increased markedly in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant even at the lowest dose 14.38 *g a.i.* ha^{-1} (4505 and 4348 kg ha^{-1}). However, the grain yield was further increased with the increase in doses being higher (4818 kg ha^{-1}) when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha^{-1} and proved significantly superior over it both lowest dose 14.38 and 19.17 g *a.i.* ha^{-1} (4505 and 4618 kg ha^{-1}, respectively). Ready mixture application of post emergence herbicide with surfactant gave better grain yield as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were significantly superior over the weedy check.

4.2.18 Straw yield (kg ha^{-1})

The mean data on straw yield of two *Rabi* season (2016-17 and 2017-18) was influenced by different weed control treatments are given in Table 4.27 and depicted through Figure 4.27.

Application of different weed control treatments brought about marked increase in the straw yield of wheat over weedy check during both the year of experimentation. Hand weeding twice (30 & 60 DAS) recorded highest mean straw yield (6647 kg ha^{-1}) whereas weedy check accounted for minimum value (4934 kg ha^{-1}). Further insight of data explicate that collective application of herbicides either as ready mixture or sequentially resulted in significantly higher straw yield of wheat over singly applied herbicides. Among herbicidal treatments, application of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant at lower dose 14.38 g *a.i*. ha^{-1} (6472 and 6417 kg ha^{-1}, respectively) which was further increased with increase in application doses being higher when Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant was applied at 23.96 g *a.i*. ha^{-1} (6562 kg ha^{-1}), being at par to 19.17 g *a.i*. ha^{-1} (6499 kg ha^{-1}). The solitary application of single herbicides resulted in lesser straw yield than mixed application but differences were significantly superior over weedy check.

4.2.17 Harvest index (%)

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to harvest index as influenced by different weed control treatments are cited in Table 4.27 and depicted through Figure 4.28.

The ratio between economic yield and biological yield (HI) expressed in percentage was affected by different weed control treatments. Among the various treatments, the minimum harvest index was recorded in weedy check (39.1 %) where weeds were not controlled. But it was increased significantly in the plots where weed control measures were adopted. Application of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant at the lower dose 14.38 g *a.i*. ha^{-1} increased the harvest index (41.1 and 40.4 %, respectively), which was further increased with increase in application doses being higher when Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant was applied at 23.95 g *a.i*. ha^{-1} (42.4 %). However, hand weeded plot registered the highest harvest index (42.6 %) but at par with higher doses herbicidal treatments.

Table 4.27. Effect of different herbicide treatments on biological, straw, grain yield (kg ha^{-1}) and harvest index (%) of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Biological Yield	Straw yield	Grain yield	Harvest index
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	10977	6472	4505	41.1
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	11116	6499	4618	41.6
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	11380	6562	4818	42.4
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	10765	6417	4348	40.4
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	10852	6409	4443	40.9
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	11103	6488	4615	41.6
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	10634	6373	4262	40.1
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	10602	6342	4260	40.2
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	10663	6376	4288	40.2
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	10542	6349	4193	39.8
T_{11}	Hand weeding twice	30 & 60 DAS	11565	6647	4919	42.6
T_{12}	Control (weedy check)	-	8103	4934	3169	39.1
SEm ±			**46.3**	**35.3**	**35.1**	**0.27**
CD (P=0.05)			**136.6**	**104.1**	**103.5**	**0.80**

4.2.18 Weed index (%)

The mean data of two *Rabi* season (2016-17 and 2017-18) related to weed index as influenced by different weed control treatments is presented in Table 4.28 and depicted through Figure 4.29.

Weed index is a measure of reduction in crop yield due to competitional stress because of weeds as compared to weed free treatment and is expressed in percentage. It is obvious from the data that different weed control treatments exerted marked effect on weed index. The maximum reduction in yield (35.6 %) occurred in plots where weeds were not controlled throughout the crop season (weedy check).

However, the application of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant at lowest dose 14.38 g *a.i.* ha^{-1} scaled down the yield reduction to the tune of (8.4 and 11.6 %, respectively). But yield reduction was further checked when Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant was applied at higher doses. Among the herbicidal treatments, the lowest weed index (2.1 %) was recorded in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant at 23.96 g *a.i*. ha^{-1} as the loss in yield was lesser which is followed by medium dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant at 19.17 g *a.i*. ha^{-1} (6.1 %), being the zero in the plots receiving hand weeding twice where maximum weeds were eliminated during critical period of crop-weed competition. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The applications of single herbicides were found to be less effective as compared to mixed application but the differences were significantly superior over the weedy check.

Table 4.28. Effect of different herbicidal treatments on weed index (%) of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Weed index (%)
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	8.4
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	6.1
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.1
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	11.6
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	9.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	6.2
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	13.4
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	13.4
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	12.8
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	14.8
T_{11}	Hand weeding twice	30 & 60 DAS	0.0
T_{12}	Control (weedy check)	-	35.6
SEm ±			**0.74**
CD (P=0.05)			**2.17**

4.2.12 Protein content (%)

The mean data of two *Rabi* season (2016-17 and 2017-18) related to protein content as influenced by different weed control treatments are presented in Table 4.29.

The different weed management practices significantly influenced the protein content over weedy check during both the year of investigation. The higher protein (13.22 %) content was recorded under hand weeding twice 30 and 60 DAS whereas, the lower protein content was recorded under weedy check (12.64 %) which was increased when weed control measures were adopted. Post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and surfactant at all doses 14.38, 19.17 and 23.96 g *a.i*. ha^{-1} (12.94, 12.83 and 13.07 %, respectively) were statistically similar in terms of protein content and proved significantly superior over unweeded check. However, hand weeded plots had maximum protein content (13.22 %) being at par to Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} (13.07) and proved superior to rest of treatment including weedy check. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The applications of single herbicides were less effective as compared to mixed application but the differences were significantly superior over the unweeded control.

4.2.13 Protein yield kg ha^{-1}

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to protein yield (kg ha^{-1}) as influenced by different weed control treatments are presented in Table 4.29.

Application of different weed control treatments brought about marked increase in the protein yield (kg ha^{-1}) of wheat over weedy check during both the year of experimentation. Hand weeding twice 30 & 60 DAS recorded highest mean protein yield (649 kg ha^{-1}) whereas, weedy check accounted for minimum value (400 kg ha^{-1}) where weeds were allowed to grow throughout crop season. Further insight of data explicate that collective application of herbicides either as ready mixture or sequentially resulted in significantly higher protein yield of wheat over singly applied herbicides. Among the herbicidal treatments, protein yield was increased markedly in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant even at the lowest dose 14.38 *g a.i.* ha^{-1} (579 and 552 kg ha^{-1}). However, the protein yield was further increased with the increase in doses being higher (629 kg ha^{-1}) when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 *g a.i.* ha^{-1} and proved significantly superior over its both lowest dose 14.38 and 19.17 g *a.i.* ha^{-1}. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The applications of single herbicides were less effective as compared to mixed application but the differences were significantly superior over weedy check.

Table 4.29. Effect of different herbicidal treatments on Protein content (%) and Protein yield kg^{-1} of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Protein content (%)	Protein yield kg^{-1}
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	12.94	579
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	12.83	597
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	13.07	629
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	12.70	552
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	13.03	569
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	12.87	596
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	12.57	537
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	12.67	540
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	12.86	548
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	12.67	533
T_{11}	Hand weeding twice	30 & 60 DAS	13.22	649
T_{12}	Control (weedy check)	-	12.64	400
SEm ±			**0.07**	**5.01**
CD (P=0.05)			**0.21**	**14.77**

4.3.1 Uptake of nitrogen by grain and straw and total crop (kg ha^{-1})

The mean data of two *Rabi* season (2016-17 and 2017-18) pertaining to uptake of nitrogen by grain and straw and total crop (kg ha^{-1}) was influenced by different weed control treatments are presented in Table 4.30.

The different weed management practices significantly increased the N uptake in grain and straw over untreated control during both the years of experimentation. The highest N uptake by grain, straw and total was observed under hand weeding twice 30 and 60 DAS (103.8, 34.0, and 137.8 kg ha^{-1} respectively). Whereas, lowest mean N uptake in grain, straw and total N uptake were recorded under untreated control (64.4, 23.2 and 87.6 kg ha^{-1} respectively).

Among the herbicidal treatments, maximum N uptake by grain, straw and total N uptake were observed when higher dose applied of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 *g a.i.* ha $^{-1}$ (100.7, 32.7 and 133.4 kg ha^{-1}, respectively) followed by application of lower dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha $^{-1}$ (95.6, 32.4 and 128.0 kg ha^{-1}, respectively) which was at par with higher dose without surfactant Halauxifen – methyl 6.95 % + Pyroxsulam 25 % 23.96 *g a.i.* ha $^{-1}$ (95.3, 31.7 and 127.0 kg ha^{-1} respectively) and proved significantly superior over all the herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were mixed significant over the unweeded control.

Table 4.30. Effect of different herbicidal treatments on nitrogen uptake by grain, straw and total uptake (kg ha^{-1}) of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Nitrogen										Total uptake
			Grain					Straw					
			Content %		Uptake		Uptake mean	Content %		Uptake		Uptake mean	
			16-17	17-18	16-17	17-18		16-17	17-18	16-17	17-18		
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.04	2.07	92.5	92.6	92.6	0.47	0.47	31.6	30.1	30.9	123.5
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.06	2.08	96.4	94.8	95.6	0.49	0.49	33.3	31.5	32.4	128.0
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.09	2.09	102.1	99.3	100.7	0.5	0.51	33.6	31.8	32.7	133.4
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.00	2.06	87.8	88.8	88.3	0.46	0.47	30.3	29.6	29.9	118.2
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.03	2.07	91.1	91.0	91.1	0.48	0.48	30.5	30.6	30.5	121.6
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.05	2.08	95.6	95.0	95.3	0.49	0.49	32.3	31.1	31.7	127.0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	1.98	2.05	83.8	87.9	85.9	0.47	0.46	30.0	29.4	29.7	115.6
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	2.00	2.05	84.9	87.7	86.3	0.47	0.47	30.6	29.5	30.0	116.3
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.01	2.07	86.2	89.0	87.6	0.47	0.46	30.7	29.4	30.0	117.6
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% **with surfactant**	47.93	1.99	2.07	83.9	86.6	85.2	0.47	0.46	30.1	28.8	29.5	114.7
T_{11}	Hand weeding twice	30 & 60 DAS	2.12	2.1	105.1	102.5	103.8	0.51	0.51	34.6	33.3	34.0	137.8
T_{12}	Control (weedy check)	-	1.99	2.05	62.5	66.4	64.4	0.46	0.46	23.4	22.9	23.2	87.6
	SEm ±				**0.92**	**0.54**	**0.73**			**0.38**	**0.28**	**0.33**	**0.65**
	CD (P=0.05)				**2.71**	**1.59**	**2.15**			**1.12**	**0.83**	**0.98**	**1.90**

4.3.2 Uptake of phosphorus by grain and straw and total crop (kg ha^{-1})

The mean data of two *Rabi* season (2016-17 and 2017-18) related to uptake of phosphorus by grain and straw and total crop (kg ha^{-1}) was influenced by different weed control treatments are presented in Table 4.31.

Data show that all weed control treatments significantly enhance the P uptake in grain and straw in comparison to weedy check during both the year of experimentation. The highest P uptake by grain, straw and total was observed under hands weeding twice 30 and 60 DAS (22.3, 10.4 and 32.7 kg ha^{-1}, respectively). Whereas, lowest mean P uptake in grain, straw and total were recorded under untreated control (13.0, 4.9 and 17.9 kg ha^{-1}, respectively). Among the herbicidal treatments, maximum P uptake by grain, straw and total were observed by applying Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 *g a.i.* ha $^{-1}$ (21.5, 9.0 and 30.5 kg ha^{-1}, respectively) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha $^{-1}$ (20.3, 7.6 and 27.9 kg ha^{-1}, respectively) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 23.96 *g a.i.* ha $^{-1}$ (20.5, 7.4 and 27.9 kg ha^{-1}, respectively) and proved significantly superior over all the herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were mixed significantly superior over the unweeded control.

Table 4.31. Effect of different herbicide treatments on phosphorus uptake by grain, straw and total crop (kg ha^{-1}) of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Phosphorus										Total uptake
			Grain					Straw					
			Content %		Uptake		Uptake mean	Content %		Uptake		Uptake mean	
			16-17	17-18	16-17	17-18		16-17	17-18	16-17	17-18		
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	0.43	0.43	19.7	19.4	19.5	0.11	0.11	7.5	7.1	7.3	26.8
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	0.44	0.44	20.6	20.0	20.3	0.12	0.12	7.8	7.4	7.6	27.9
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	0.45	0.45	21.9	21.2	21.5	0.14	0.14	9.2	8.8	9.0	30.5
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	0.44	0.44	19.3	18.9	19.1	0.1	0.10	6.6	6.3	6.4	25.5
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	0.44	0.44	19.9	19.5	19.7	0.11	0.11	7.2	6.9	7.0	26.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	0.44	0.44	20.6	20.3	20.5	0.11	0.11	7.5	7.2	7.4	27.9
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	0.44	0.44	18.8	19.0	18.9	0.11	0.11	7.0	7.0	7.0	25.9
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	0.44	0.44	18.6	18.7	18.6	0.11	0.11	6.8	6.8	6.8	25.4
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	0.45	0.45	19.1	19.2	19.2	0.11	0.11	7.0	7.0	7.0	26.2
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	0.44	0.44	18.7	18.5	18.6	0.11	0.11	7.0	7.0	7.0	25.6
T_{11}	Hand weeding twice	30 & 60 DAS	0.45	0.45	22.5	22.1	22.3	0.16	0.16	10.6	10.2	10.4	32.7
T_{12}	Control (weedy check)	-	0.38	0.44	11.9	14.1	13.0	0.10	0.10	4.8	5.0	4.9	17.9
	SEm ±				0.37	0.31	0.34			**0.40**	**0.41**	**0.41**	**0.48**
	CD (P=0.05)				1.09	0.92	1.01			**1.18**	**1.19**	**1.19**	**1.41**

4.3.3 Uptake of potash by grain and straw and total crop (kg ha^{-1})

The mean data of two *Rabi* season (2016-17 and 2017-18) related to uptake of potash by grain and straw and total uptake (kg ha^{-1}) was influenced by different weed control treatments are presented in Table 4.32.

The different weed management treatments significantly increase the K uptake in grain and straw over untreated control during both the year of experimentation. The highest K uptake by grain, straw and total was observed under twice hand weeding 30 and 60 DAS (26.9, 72.4 and 101.3 kg ha^{-1} , respectively) whereas, lowest mean K uptake in grain, straw and total were recorded under untreated control (16.4, 48.7 and 65.1 kg ha^{-1}, respectively). Among the herbicidal treatments, maximum P uptake by grain, straw and total were observed by applying Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 *g a.i.* ha $^{-1}$ (26.5, 73.5 and 100.0 kg ha^{-1}, respectively) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.14 *g a.i.* ha $^{-1}$ (24.5, 67.8 and 92.3 kg ha^{-1}, respectively) which was at par with Halauxifen – methyl 6.95 % + Pyroxsulam 25 % without surfactant 23.96 *g a.i.* ha $^{-1}$ (24.6, 66.2 and 90.8 kg ha^{-1}, respectively) and proved significantly superior over all the herbicidal treatments. Ready mixture application of post emergence herbicide with surfactant gave better result as compared to application without surfactant. The application of single herbicides was less effective as compared to mixed application but the differences were mixed significantly superior over the unweeded control.

Table 4.32. Effect of different herbicide treatments on potash uptake by grain, straw and total crop (kg ha^{-1}) of wheat

Treatment		Dose (g *a.i.* ha^{-1})	Potash										Total uptake
			Grain					Straw					
			Content %		Uptake		Uptake mean	Content %		Uptake		Uptake mean	
			16-17	17-18	16-17	17-18		16-17	17-18	16-17	17-18		
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	0.52	0.52	23.6	23.3	23.4	0.98	0.98	65.5	61.8	63.6	87.0
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	0.53	0.53	24.9	24.1	24.5	1.04	1.04	69.7	65.9	67.8	92.3
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	0.55	0.55	26.9	26.1	26.5	1.12	1.12	75.3	71.7	73.5	100.0
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	0.52	0.52	22.7	22.2	22.5	0.99	0.99	64.7	61.9	63.3	85.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	0.52	0.52	23.5	23.1	23.3	1.0	1.00	65.2	63.0	64.1	87.4
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	0.53	0.53	24.8	24.4	24.6	1.02	1.02	67.6	64.7	66.2	90.8
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	0.52	0.52	21.9	22.1	22.0	0.97	0.97	62.0	62.0	62.0	84.0
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	0.52	0.52	21.9	22.1	22.0	0.94	0.94	59.8	59.9	59.8	81.8
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	0.53	0.53	22.7	22.8	22.7	0.91	0.91	58.1	57.9	58.0	80.7
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	0.52	0.52	21.8	21.6	21.7	0.9	0.9	57.1	56.8	56.9	78.6
T_{11}	Hand weeding twice	30 & 60 DAS	0.55	0.55	27.1	26.7	26.9	1.12	1.12	76.0	72.9	74.4	101.3
T_{12}	Control (weedy check)	-	0.52	0.52	16.2	16.5	16.4	0.99	0.99	47.8	49.6	48.7	65.1
	SEm ±				**0.33**	**0.30**	**0.32**			**1.89**	**1.93**	**1.91**	**1.93**
	CD (P=0.05)				**0.98**	**0.89**	**0.94**			**5.59**	**5.68**	**5.64**	**5.68**

4.4.1 Economic analysis of the treatments

The economic analysis of treatments was determined on per hectare area basis, which include cost of cultivation, gross monetary returns, net monetary returns and benefit-cost ratio (profitability per rupee of investment) under different treatments and data are presented in Table 4.33.

Cost of cultivation

Cost of cultivation was determined treatment wise on the basis of market price of various common and variable agro-inputs used (Appendix - XXXIII). The values thus obtained are presented in Table 4.33. Data showed that the cost of cultivation of wheat varied due to weed control practices. Weedy check plots had the lowest cost of cultivation (₹ 30648 ha^{-1}), which increased in the range of 32143 to Rs 33718 ₹ ha^{-1} with increase in application doses of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 14.38 to 23.96 g ha^{-1} under herbicidal treatments. Whereas, it was maximum under hand weeding (36648 ₹ ha^{-1}) where weeds were removed manually twice at 30 and 60 days after sowing which needed 30 man days, suggesting that weed control through herbicides is cheaper than manual hand weeding.

Gross monetary returns (₹ ha^{-1})

Gross monetary returns (GMRs) under different treatments was determined on the basis of value of main and by product obtained from wheat crop under particular treatment. It was obvious from two years mean data that the gross monetary returns (GMR) was minimum (64850 ₹ ha^{-1}) under weedy check because of the lowest grain and straw yields (Table 4.33). But, it was increased appreciably with the adoption of weed control measures as the gross monetary returns had positively association with the yields and economic value of crop. Among the herbicidal treatments in combination with surfactant, the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} fetched higher GMR (96716 ₹ ha^{-1}) closely followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.17 g *a.i*. ha^{-1} (93111 ₹ ha^{-1}) and proved better over other herbicidal combinations. However, the GMR was maximum (98629 ₹ ha^{-1}) under hand weeding treatment.

Net monetary returns (₹ ha^{-1})

The net monetary returns (NMR) under each treatment was determined by subtracting the cost of cultivation from gross monetary returns (GMR) of the particular treatment. The treatment wise values, thus obtained, are given in Table 4.33.

Table 4.33. Economic analysis of different weed control treatments in wheat

Treatment		Dose (g *a.i.* ha^{-1})	cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	32143	91106	58963	2.8
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	32368	93111	60743	2.9
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	32593	96716	64123	3.0
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	32023	88271	56248	2.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	32248	89904	57656	2.8
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	32473	93045	60572	2.9
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	31818	86682	54864	2.7
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	31868	86594	54726	2.7
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	31693	87139	55446	2.8
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	33718	85438	51720	2.5
T_{11}	Hand weeding twice	30 & 60 DAS	36648	98629	61981	2.7
T_{12}	Control (weedy check)	-	30648	64850	34202	2.1

It was obvious from the data that NMR was minimum (34202 ₹ ha^{-1}) in weedy check plot when crop was not weeded throughout the crop season which increased remarkably under all the plots receiving weed control measures. However, Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} was more profitable than any other weed control treatments which fetched the highest value of NMR (64123 ₹ ha^{-1}) followed by hand weeding twice (61581 ₹ ha^{-1}).

Benefit - cost ratio (₹ ha^{-1})

It refers to net monetary gain under a particular treatment with each rupee of investment. The data on benefit-cost ratio as affected by different herbicidal treatments have been given in the Table 4.33. It was evident from the data that under weedy check there was gain of 2.1 paisa per rupee of investment where, weeds were allowed to grow throughout the crop season. But profitability was increased identically with the adoption of weed management practices. However, the highest benefit-cost ratio was registered under the post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} (3.0) followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 19.17 g *a.i*. ha^{-1} (2.9) over other treatment combinations even to hand weeding done at different point of time.

4.5.1 Soil chemical properties

Data related to physico-chemical properties of soil after crop harvest as effect of different herbicide treatments on during both the years of experimentation are presented in Table 4.34.

Perusal of the data clearly indicates that effect of different herbicide treatments did not affect the physico-chemical properties of the soil *viz*., pH , EC and organic carbon significantly.

Available N, P and K in Soil after harvest

Data related to available N, P and K after harvest in soil an effect of different herbicide treatments during both the year of experimentation are presented in Table 4.35. Scrutiny of the data clearly indicates that effect of different herbicide treatments failed to affect significantly the residual N P and K content in soil. However, the highest N P K content in soil after harvest was observed in the plots of.

Table 4.34. Effect of different herbicidal treatment on chemical properties of soil after crop harvest

Treatment		Doses g *a.i.* ha^{-1}	pH			EC			OC		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	7.19	7.21	7.20	0.29	0.30	0.30	0.54	0.53	0.54
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	7.11	7.13	7.12	0.28	0.29	0.29	0.54	0.54	0.54
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	7.14	7.16	7.15	0.28	0.31	0.30	0.54	0.53	0.54
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	7.19	7.18	7.19	0.31	0.30	0.31	0.53	0.53	0.53
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	7.10	7.12	7.11	0.28	0.29	0.29	0.55	0.54	0.55
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	7.10	7.13	7.12	0.29	0.30	0.30	0.54	0.54	0.54
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	7.20	7.15	7.18	0.28	0.29	0.29	0.53	0.54	0.54
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	7.18	7.20	7.19	0.28	0.29	0.29	0.53	0.53	0.53
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	7.14	7.16	7.15	0.29	0.30	0.30	0.53	0.54	0.54
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	7.15	7.17	7.16	0.29	0.29	0.29	0.54	0.54	0.54
T_{11}	Hand weeding twice	30 & 60 DAS	7.25	7.19	7.22	0.30	0.31	0.31	0.53	0.55	0.54
T_{12}	Control (weedy check)	-	7.11	7.13	7.12	0.30	0.29	0.30	0.54	0.54	0.54
SEm ±			**0.27**	**0.18**	**0.23**	**0.24**	**0.57**	**0.41**	**0.11**	**0.23**	**0.17**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value			**7.5**			**0.29**			**0.54**		

Table 4.35. Effect of different herbicidal treatment on chemical properties of soil after crop harvest

Treatment		Doses g *a.i.* ha^{-1}	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
			2016-17	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	266.76	266.72	266.74	12.3	12.47	12.39	0.54	0.53	0.54
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	267.66	267.2	267.43	13.7	12.93	13.32	0.54	0.54	0.54
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	269.37	268.32	268.85	13.1	13.00	13.05	0.54	0.53	0.54
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	266.57	266.69	266.63	12.8	12.25	12.53	0.53	0.53	0.53
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	267.02	267.19	267.11	12.6	12.62	12.61	0.55	0.54	0.55
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	267.42	266.99	267.21	12.7	12.77	12.74	0.54	0.54	0.54
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	265.98	266.02	266.00	12.5	12.55	12.53	0.54	0.54	0.54
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	266.25	266.11	266.18	12.3	12.47	12.39	0.53	0.53	0.53
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	266.26	266.08	266.17	12.5	12.55	12.53	0.54	0.54	0.54
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	266.75	266.65	266.70	12.2	12.40	12.30	0.54	0.54	0.54
T_{11}	Hand weeding twice	30 & 60 DAS	266.98	267.18	267.08	12.5	12.85	12.68	0.54	0.55	0.54
T_{12}	Control (weedy check)	-	266.21	267.0	266.61	12.4	12.47	12.44	0.54	0.54	0.54
SEm ±			**0.27**	**0.63**	**0.72**	0.29	0.17	0.23	**0.23**	**0.17**	**0.17**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value			**260.12**			**12.25**			**295.10**		

4.6.1 Study on succeeding soybean crop

4.6.1.1 Emergence (%)

The data give in Table 4.36 show that persistence effect of different herbicides applied in wheat crop was found non-significant on emergence (%) of succeeding soybean crop during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There was no any statistically difference between treatments

Table 4.36. Effect of different herbicidal treatments on emergence (%) of succeeding soybean crop

Treatment		Dose (g *a.i.* ha^{-1})	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	85	86	85.50
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	87	86	86.50
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	85	88	86.50
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	86	85	85.50
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	87	88	87.50
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	86	86	86.00
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	86	87	86.50
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	85	86	85.50
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	85	86	85.50
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	89	87	88.00
T_{11}	Hand weeding twice	30 & 60 DAS	85	86	85.50
T_{12}	Control (weedy check)	-	87	87	87.00

4.6.1.2 Plant population

The results on residual effect of different weed management practices employed in wheat crop on plant population at initial stage (at 15 DAS) and at harvest of succeeding soybean crop, are presented in Table 4.37 and graphically represented in Figure 4.30.

The results reveal that carry over effect of different herbicides applied in wheat crop was found non-significant on plant population of succeeding soybean crop recorded at 15 DAS and at harvest after harvesting of wheat in the same plots during both the years. The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop. There were no any statistically difference between treatments but mathematically changes were recorded under different herbicidal treatments. At 15 DAS highest plant population was recorded when (T_4) Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant applied at lowest dose 14.38 g *a.i*. ha^{-1} (17.8) followed by T_3 (17.7), T_7 (17.7) and T_{11} (17.7). At harvest highest plant population was recorded when Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant applied at lowest dose 14.38 g *a.i*. ha^{-1} (17.2) and same plant population was recorded under T_8 (17.2).

Table 4.37. Effect of different herbicidal treatments on plant population of succeeding soybean crop

Treatment		Dose (g *a.i.* ha^{-1})	15 DAS			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	17.2	17.5	17.3	16.8	16.5	16.7
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	17.3	17.2	17.3	17.0	16.8	16.9
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	17.5	17.7	17.6	17.2	16.9	17.1
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	17.8	17.8	17.8	17.1	17.2	17.2
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	17.6	17.6	17.6	16.9	16.9	16.9
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	16.5	16.8	16.7	16.1	15.9	16.0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	17.4	17.7	17.5	16.7	16.7	16.7
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	18.0	17.3	17.7	17.3	17.0	17.2
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	18.0	17.3	17.6	17.5	16.9	17.2
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	16.8	17.2	17.0	16.3	17.0	16.7
T_{11}	Hand weeding twice	30 & 60 DAS	18.0	17.4	17.7	17.4	16.9	17.1
T_{12}	Control (weedy check)		16.5	17.6	17.0	16.9	16.9	16.9
SEm ±			**2.42**	**0.40**	**0.30**	**0.35**	**0.39**	**0.23**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.6.3 Phytotoxic symptoms on succeeding soybean crop plant at 15, 30 and 45 DAS

The results on residual effect of different weed management practices employed in wheat crop on branches plant^{-1} of succeeding soybean crop at 15, 30, 45 DAS.

The results revealed that carry over effect of different herbicides applied in wheat crop was found non-significant on crop plant of succeeding soybean crop recorded at 15, 30, 45 DAS after harvesting of wheat in the same plots during both the years. The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

4.6.4 Branches plant^{-1}

The results on residual effect of different weed management practices employed in wheat crop on branches plant^{-1} of succeeding soybean crop at 30, 60, 90 DAS and at harvest, are presented in Table 4.38 and graphically represented in Figure 4.36.

The results revealed that carry over effect of different herbicides applied in wheat crop was found non-significant on branches plant^{-1} of succeeding soybean crop recorded at 30, 60, 90 DAS and at harvest after harvesting of wheat in the same plots during both the years. The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop on succeeding crop. There were no any statistically difference between treatments but mathematically changes were recorded under different herbicidal treatments.

At 30 DAS highest number of branches plant^{-1} was recorded when (T_4) Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant applied at lowest dose 14.38 g *a.i*. ha^{-1} (2.8) and lowest number of branches plant^{-1} was recorded under T_1 Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant applied at lowest dose 14.38 g *a.i*. ha^{-1} (2.3), T_8 Halauxifen-methyl 10.42% with surfactant 5.21 g *a.i*. ha^{-1} (2.3) and T9 Sulfosulfuron + Metsulfuron – methyl 80 with surfactant 32 g *a.i*. ha^{-1} (2.3).

At 60 DAS highest number of branches plant^{-1} was recorded under T_5 Halauxifen – methyl 6.95% +Pyroxsulam 25% without surfactant applied at medium dose 19.17 g *a.i.* ha^{-1} (2.8) and lowest number of branches $plant^{-1}$ was recorded under T_6 Halauxifen – methyl 6.95% +Pyroxsulam 25% without surfactant applied at higher dose 23.96 g *a.i.* ha^{-1} (2.5) and T_{12} weedy check (2.5).

Table 4.38. Effect of different herbicidal treatments on branches $plant^{-1}$ of succeeding soybean crop (mean data of two season)

Treatment		Dose (g *a.i.* ha^{-1})	30 DAS	60 DAS	90 DAS	At harvest
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.3	2.6	3.4	3.4
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.5	2.6	3.4	3.4
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.6	2.7	3.4	3.4
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.8	2.7	3.4	3.4
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.4	2.8	3.5	3.5
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.4	2.5	3.4	3.4
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.6	2.7	3.5	3.5
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	2.3	2.6	3.5	3.5
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.3	2.6	3.5	3.5
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% **with surfactant**	47.93	2.5	2.7	3.5	3.5
T_{11}	Hand weeding twice	30 & 60 DAS	2.5	2.6	3.6	3.6
T_{12}	Control (weedy check)	-	2.6	2.5	3.5	3.5
SEm ±			0.22	0.16	0.08	0.08
CD (P=0.05)			NS	NS	NS	NS

At 90 DAS highest number of branches plant^{-1} was recorded under T_{11} hand weeding twice at 30 and 60 DAS (2.6) and lowest number of branches plant^{-1} was recorded under T_1, T_2, T_3, T_4 and T_6 (3.4) and same trend also fund at harvest.

4.6.5 Yield attributing characters

The data on persistence effect of different herbicides applied in wheat crop on yield attributing characters *viz*. pods plant^{-1}, seed pod^{-1} and seed index of succeeding soybean crop was recorded at harvest are presented in Table 4.39 and the data are also graphically depicted in Fig.4.32.

4.6.6 Number of pods plant^{-1}

The data indicated that persistence effect of different herbicides applied in wheat crop was found non-significant on pods plant^{-1} of succeeding soybean crop at harvest during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest pods plan^{-1} was recorded under application of T_7 Pyroxsulam 4.5% with surfactant 18.75 g *a.i.* ha^{-1} (46.2 pods plan^{-1}) and lowest pods plant^{-1} was recorded under T_{12} weedy check (44.0 pods plan^{-1}). The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

4.6.7 Number of seed pod^{-1}

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant seed pod^{-1} of succeeding soybean crop at harvest during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest seed plan^{-1} was recorded under application of T_{12} weedy check (2.4 seed pod^{-1}) and lowest seed plant^{-1} was recorded under T_{10} Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 (1.8 seed pod^{-1}). The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop on succeeding crop.

Table 4.39. Effect of different herbicidal treatments on yield attributes of succeeding soybean crop

Treatment		Dose (g *a.i.* ha^{-1})	Pods $plant^{-1}$	Seed pod^{-1}	Seed index (g)
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	45.4	2.0	9.5
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	44.1	2.0	9.5
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	44.2	2.1	9.6
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	45.7	2.3	9.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	42.4	2.2	9.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	43.3	2.1	9.6
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	46.2	2.2	9.8
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	43.7	2.3	9.6
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	44.5	2.0	9.7
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	45.7	1.8	9.4
T_{11}	Hand weeding twice	30 & 60 DAS	41.8	2.1	9.8
T_{12}	Control (weedy check)	-	44.0	2.4	9.5
SEm ±			0.22	1.46	0.17
CD (P=0.05)			NS	NS	NS

4.6.8 Seed index (%)

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant on seed index of succeeding soybean crop at harvest during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest seed index was recorded under different treatments *viz*. T_4, T_7 and T_{11} (9.8, 9.8, 9.8 g, respectively) and lowest seed index was recorded under T_{10} Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 (9.4 g). The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

4.6.9 Yield

The data on persistence effect of different herbicides applied in wheat crop on seed yield kg ha^{-1}, straw yield kg ha^{-1} and harvest index of succeeding soybean crop was recorded are presented in Table 4.40 and the data are also graphically depicted in Fig.4.33.

4.6.10 Seed yield (kg ha^{-1})

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant on seed yield of succeeding soybean crop after harvest during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest seed yield kg ha^{-1} was recorded under T_8 Halauxifen-methyl 10.42% with surfactant alone application at 5.21 g *a.i*. ha^{-1} (1889 kg ha^{-1}) and lowest yield was recorded under T_5 Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant at highest dose 47.95 g *a.i*. ha^{-1} (1730 kg ha^{-1}). The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

4.6.11 Straw yield (kg ha^{-1})

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant on straw yield of succeeding soybean crop at harvest during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest straw yield kg ha^{-1} was recorded under T_3 Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at higher dose 23.96 g *a.i.* ha^{-1} (3985 kg ha^{-1}) and lowest straw yield kg ha^{-1} was recorded under T_2 Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at higher dose 19.17 g *a.i.* ha^{-1} (3689 kg ha^{-1}). The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

4.6.12 Harvest index (%)

The analysis of data showed that persistence effect of different herbicides applied in wheat crop was found non-significant on harvest index (%) of succeeding soybean crop at harvest during both the years. The results clearly showed that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest harvest index was recorded under T_{10} Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 (35 %) and lowest harvest index was recorded under T_3 Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at higher dose 23.96 g *a.i.* ha^{-1} (31 %) and T_5 Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant at medium dose 19.17 g *a.i.* ha^{-1} (31 %). The results clearly indicated that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

Table 4.40. Effect of different herbicidal treatments on seed, straw yield and harvest index of succeeding soybean crop (mean data of two season)

Treatment		Dose (g *a.i.* ha^{-1})	Seed yield (kg ha^{-1})	Straw yield kg ha^{-1})	Harvest index (%)
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	1830	3717	33
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	1811	3689	33
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	1821	3985	31
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	1861	3874	32
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	1730	3826	31
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	1844	3607	34
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	1878	3719	34
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	1889	3791	33
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	1882	3867	33
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1860	3481	35
T_{11}	Hand weeding twice	30 & 60 DAS	1878	3874	33
T_{12}	Control (weedy check)	-	1848	3826	33
SEm ±			0.22	59.24	144.46
CD (P=0.05)			NS	NS	NS

DISCUSSION

The present investigation conducted for two consecutive years during *Rabi* seasons (2016-17 and 2017-18) on the same site without changing layout plan. Several observations regarded on weed dynamics, wheat crop growth parameters, yield attributing traits, yield and economic analysis of treatments. Results are described in previous chapter. The significant findings are discussed in this chapter with the support of generated data during the course of field experimentation and views endorsed by other researchers including scientific facts. The photographs of the crops under different weed control practices, as the yield is final yardstick for the evaluation of the efficiency of different treatments, the discussion, therefore, is necessarily centralized on the effect of treatments on various characters as they finally decide the yield.

In general, the productivity of crops has much concern with the existing agro-climatic conditions of the locality besides the influence of the treatments tested under present investigation. Therefore, the weather conditions of the experimental area could not be ignored. Hence, a brief account on prevailing soil and weather conditions of the experimental area are also described in this chapter.

5.1 Edaphic and climatic variations

The type and extent of weed flora in cropped area mainly depends on the soil type and climatic conditions of the area besides the impact of cultural practices that are followed under the particular cropping system over the years. The plant at any stage of growth is a product, not only of its gene but also the environmental conditions in which it is matured. Thus, the growth, development and finally the grain yield are greatly influenced due to prevailing weather conditions (particularly temperature, rainfall, humidity, *etc*.), which prevailed during the crop season. This becomes the decisive index for harnessing the final yield of the crop and was almost normal as per average conditions of the locality. Thus, it could be said that soil and weather conditions were uniform for all the treatments and whatever variations were observed under different treatments. The weekly meteorological data during the course of investigation recorded during crop season at Meteorological Observatory, College of Agriculture Engineering, JNKW, Jabalpur, are presented in Table 3.1. It is obvious from the meteorological data that the weather conditions during the crop season were favorable for the growth and development of wheat. Overall, almost all the weather conditions during both *Rabi* seasons were normal. The maximum and minimum temperature slightly deviated during the year of experimentation over the normal data. The maximum temperature during whole season was towards the lower side during 2016-17 and higher side during 2017-18 as compared to normal maximum temperature of the locality. While, minimum temperature was towards lower side during both the crop seasons. Thus, total thermal requirement of wheat crop was almost compensated within the period of time. The rainfall was slightly higher during 2017-18 and lower during 2016- 17 and did not much affect the growth and yield of crop. Other weather parameters did not deviate much from their mean values during entire cropping season. All the weather conditions were congenial and did not alter the effect of treatments, crop growth as well as yield. The soil properties of the experimental area are described in Table 3.2. It is obvious from the data given in the foresaid table that soil of the experimental area is sandy clay loam in texture, neutral in reaction (pH 7.20), medium in organic carbon content (0.54%), normal in electrical conductivity (0.29 dS m^{-1}), medium in available N (260.12 kg ha^{-1}), P (12.25 kg ha^{-1}) and high in available K (295.10 kg ha^{-1}). As a whole, the soil of the experimental field was almost representative to the soils existing in wheat growing areas of the agro-climatic zone. Since, the soil conditions of the experimental area are representative to the majority of the soils belonging to predominant area of wheat in Kymore Plateau and Satpura hill agro-climatic zone, hence the findings of the present investigation may be applicable in almost all wheat growing pockets of the zone.

5.2 Effect on weed dynamics

The weed density as affected by weed control practices was studied in wheat crop during both the years of investigation. The density and dry weight of all weeds were recorded before herbicide application, at 30 DAA, 45 DAA and harvest stage of crop during both the years and later have been averaged out and same are presented as mean data for 30 DAA in previous chapter (Table 4.2

to 4.13). In the present investigation, "**Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat**" was adopted continuing for 2 years on same site without changing layout plan of treatments. Henceforth, these weed control practices might have exerted their own influence on existence, population and type of weed flora in the concerning crop components. The floristic composition of weeds under a particular crop mainly depends upon the existing agro-ecosystem and cultural practices adopted to grow the crop.

The different weed control practices significantly influenced the density and dry weight of weeds in wheat. Density and dry weight of *Cyprus iria, Medicago denticulata, Cichorium intybus, Anagallis arvensis, Chenopodium* album and *Medicago truncatula* were significantly higher under weedy check at 30 DAA due to uninterrupted growth of weeds as no weed control measures were adopted in weedy check plots. However, identical reduction in density and dry weight of weeds was observed when weeds were controlled either chemically or manually. The application of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant at the lowest dose 14.38 g *a.i.* ha^{-1} caused less reduction in density and dry weight of dicot weeds but reduction was more pronounced when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at higher dose from 19.17 to 23.96 g *a.i.* ha^{-1}. The presence of Halauxifen – methyl 6.95 % + Pyroxsulam 25% in non-lethal concentration at the site of action could be the reason for poor activity of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % against dicot weeds when applied at the lowerdose (14.38 g *a.i.* ha^{-1}) but the reverse was true when it was applied at higher dose. Tested herbicide Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant at 23.96 g *a.i.* ha^{-1} as post emergence caused more reduction in the density and dry weight of dicot weeds. Similar results were also endorsed by Singh *et al.* (2015) Arora *et al.* (2013). Hand weeding twice at 30 and 60 DAS reduced the density including dry weight of weeds to the maximum extent over herbicidal treatments due to elimination of all sort of weeds (monocot and dicot) during the course of hand weeding. Similar results were also reported by Ali *et al.* (2003) and Yadav and Dixit (2014). They have reported that the hand weeding treatments performed better than all the herbicidal treatments in reducing the density and biomass of weeds.

It is evident from the data given in (Table 4.1) that density and relative density of dicot weeds in weedy check were higher (88.1 and 88.3 %) as compared to monocot weeds (11.9 and 11.7 %) during both the years of experimentation indicating predominance of dicoct weeds in the experimental field of wheat crop. the monocot, *Cyprus iria* was more rampant constituting 11.9 and 11.7 % relative density of total weeds, whereas *Medicago denticulate* was dominant among the dicots (28.9 and 29.9 %). Besides these, *Medicago truncatula* (23.3 and 21.1 %), *Chenopodium album* (14.0 and 14.2 %), *Anagallis arvensis* (11.1 and 12.0 %), *Cichorium intybus* (10.8 and 11.1 %), also marked their good presence in the experimental field during both the years. The experimental field was infested with both monocot and dicot weeds. Almost similar weed flora associated in wheat was also reported by Tiwari *et al.* (2015), khan *et al.* (2017) and singh *et al.* (2015).

Different weed management practices exerted their remarkable effect on weed index (Table 4.29), weed control efficiency (Table 4.15). Weed index is a measure of reduction in crop yield due to competition stress because of weeds as compared to weed free treatment and is expressed in percentage. It is obvious from the data that different weed control treatments exerted marked effect on weed index. The maximum reduction in yield (35.6 %) occurred in plots where weeds were not controlled throughout the crop season (weedy check). However, among the herbicidal treatments, the lowest weed index (2.1 %) was recorded in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant at 23.96 g *a.i.* ha^{-1} as the loss in yield was lesser which was followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant at 19.17 g *a.i*. ha^{-1} (6.1 %).This was due to lower weed population and lower dry matter production of weeds during initial stage by pre-emergence application of this herbicide and control of later weeds through hand weeding provided weed free and congenial environment to the crop. It was in line with respect to the findings of many workers (Devi *et al*. 2018, Ziar *et al.* 2017, Kumar *et al.* 2011).

Weed control efficiency of a treatment has strong negative association with weed biomass. Therefore, the trend of treatments for increased WCE was in order of weed biomass. Different weed control practices caused the marked variation on weed control efficiency in wheat. In the present study, it was observed that all the weeds had higher density and dry weight in weedy check where no weed control measures were adopted in weedy check. However, the density and dry weight of all weeds were identically reduced with the adoption of weed control measures either chemically or manually. Post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with and without surfactant at the lower dose 14.38 g *a.i.* ha^{-1} caused appreciable reduction (Table 4.14) in dry weight of monocot and dicot weeds while its activity was poor against narrow and broad leaf weeds. But weed control efficiency of Halauxifen – methyl 6.95 % + Pyroxsulam 25% against all the weeds was further increased correspondingly with increase in dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25% with surfactant from 14.38 to 23.96 g *a.i*. ha^{-1} being the maximum in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25% at higher dose with surfactant 23.96 g *a.i*. ha^{-1}. Sharma (2009) also found that the weed control efficiency increased from 81.3% to 91.3% Singh and Ali (2004) reported that the weed control efficiency was 78.2, 82.9 and 80.5%. Rana *et al.* (2017), Stanzen *et al.* (2017) and Singh *et al.* (2015). Control levels can vary from 20 to 100%, with both recommended and reduced doses. Herbicide when applied without surfactant, makes 145^0 angle between droplet and leaf surface and that's why there was less penetration, absorption and less amount reached at the site of action in non lethal concentration but, herbicide applied with surfactant it makes 75^0 angle and there was more contact between leaf surface and herbicide for more time on leaf. Beside this, it decreased surface tension which helps to improve penetration through leaf cuticle, wetting and spreading ability that's why herbicide reached in more concentration at the site of action and consequently check the weed growth (Roggenbuck *et al.,* 1993, Gaskin and Holloway, 1992).

However, in present experiment the maximum weed control efficiency was recorded under hand weeded plots due to complete elimination of both monocot as well as dicot weeds during the course of hand weeding at 30 DAS. Similar views have also been observed by as they also found that the hand weeding treatment performed better than all the herbicidal treatments in reducing the density, biomass of weeds and recorded maximum weed control efficiency (92.2%).

5.3 Study on wheat crop

5.3.1 Plant population

Plant population was recorded 15 DAS and at harvest. Result showed that the plant population at 15 DAS was not affected due to herbicidal treatments (Table 4.15) because plant population was recorded before application of herbicides and hence, germination and emergence of crop was not affected by herbicidal treatments. Similarly, at harvest, all the plots receiving different weed control treatments had similar plant population of wheat to that weedy check and hand weeded plots as the herbicidal treatments did not cause mortality of wheat seedlings and henceforth the plant population in all the treatments was alike. The visual observations indicated that post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at higher dose 47.93 g *a.i*. ha^{-1} exhibited slight phytotoxic effect on wheat plants in terms of yellowing of leaves in the initial stage but plants recovered soon and attained the normal growth after 20 days of herbicide application and there was no mortality of crop plants.

5.3.2 Growth parameter

In general, crop growth parameters *viz.,* plant height, number of tillers, crop biomass, leaf area index, chlorophyll content, crop growth rate and relative growth rate *etc*. attained lower values in weedy check plots due to severe competition and smothering effect by weeds where weeds were not controlled. While, lower values of plant height (Table 4.16) was recorded under higher dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 47.93 g *a.i*. ha^{-1} and this may be due to slight phytotoxic effect which resulted into stunting growth compared to the other herbicidal treatments. Similarly, Kaur and Brar (2014) also reported that higher dose of herbicides resulted in significant less height than its lower dose at harvest. This might be due to toxic effect of herbicide (Chandi, 2004 and Soltani and Saeedipour, 2015).

Numbers of tillers were maximum (Table 4.18) in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i*. ha^{-1} followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 19.17 g *a.i*. ha^{-1} which was at par with hand weeded plots. The increase in the number of tiller could be due to many reasons. First reason being the early development of tillers was due to enhanced translocation of photosynthates from main shoot (Lauer and Simmons, 1985). Second one could due to slower growth rate in the main stem apical meristem induced by greater concentration of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} might have caused a shift in assimilate transport to the tiller buds which gave them an earlier start with a better chance of survival. In addition, lower concentration of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant in the tiller buds might have a stimulatory effect. Hence, all these resulted into the proportionate horizontal and vertical expansion of shoot as the plant inverts more biomass in lateral growth rather than in plant height.

Crop biomass during both the years of experimental, application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1} recorded the highest dry matter accumulation (Table 4.19). The results of the investigation presented in the preceding chapter (Table 4.19) reflect that various weed control treatments provided significant improvement in growth characters of wheat crop. Greater dry matter accumulation by the 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 the optimum expansion of leaves as early as possible. 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 thereby more accumulation of dry matter (Duncon, 1971 and Korpff, 1993). This was well established by presence of significant negative correlation between crop growth and weed dry matter at successive growth stages. These results also corroborate with the finding of Tunio *et al.*

(2004), Khan *et al.* (2005), Pandey *et al.* (2006), Ahmed and Tarique (2010) and Pradhan and chakraborti (2010).

Leaf area index is the yardstick for measuring the photosynthetic efficiency of crops. Weed control treatments had the positive effect on the LAI during the crop development stage (Table 4.25). Results showed that LAI of the wheat was increased from the beginning of crop growth stage up to 60 DAS and afterwards, it decreased. The highest LAI was recorded in hand weeding twice (30 & 60 DAS), while the lowest was observed in unweeded control. Among the herbicidal treatment LAI was observed with application Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1}. It might be ascribed to rate of early increase in LAI was dependent on light and temperature conditions. It is an accent parameter with a positive correlation on wheat yield. The present investigation clearly indicated that all these combined herbicidal treatments effectively controlled narrow as well as broad leaf weeds at 30 DAA stages and thus helped the wheat crop to grow better with higher leaf expansion, finally resulting in higher values for leaf area index.

Crop growth rate (CGR) was also influenced by different weed control treatments at all crop growth stages except 30 DAS. The maximum CGR was obtained under weed free plot followed by different herbicidal treatment and all these treatments were at par with each other at 60 DAS (Table 4.22). It may possible due to lesser weed competition and higher LAI under these treatments. These results also corroborate with the finding of Kumar *et al*. (2003).

Relative growth rate (RGR) indicates rate of growth per unit dry matter. The RGR was lower at early stages and increased up to 60 DAS thereafter it was decreased toward maturity stages (Table 4.23). These results are in line with the findings of Shukla and Warsi (2002) who reported that maximum RGR of wheat at 35- 45 DAS. Weed control treatments significantly influenced this parameter at 60 DAS. The maximum value of RGR was noted in weed free plot, which was statistically similar with application of herbicidal treatments. It might be due to effective weed control of narrow as well as broad leaf weeds under these treatments. However, all the growth parameters of crop were considerably more under hand weeded plots compared to rest of the treatments because crop was free from weed stress and all the growth resource optimally utilized by the crop plants. This finally led to better growth and development of ear head. The values of other crop growth parameters was increased appreciably when weed control measures were adopted. Application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at lower dose 14.38 g *a.i*. ha^{-1} caused appreciable increase in all the growth parameters, being higher when it was applied at higher dose 23.96 g *a.i*. ha^{-1}. This may be because of better supply of growth resources and minimal crop-weed competition without any phytotoxic effect on wheat crop.

Chlorophyll content, maximum reduction in chlorophyll content (Table 4.21) in wheat leaves was observed when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant applied at higher rate 47.93 g *a.i*. ha^{-1} and this behavior can be explained on the basis of increased reactive oxygen species production, which in turn resulted in damage to photosynthetic apparatus. Nabiha *et al.* (2014) also observed that total chlorophyll including chlorophyll a and chlorophyll b, decreased with increased chevalier herbicide concentrations (0.6, 0.9, 1.2 and 1.5 mg/plot) in wheat leaves. The above findings are in accordance with results given by El-Rokiek *et al*. (2012). Wang and Zhou (2006) conducted an experiment to find out the effects of herbicide chlorimuron-ethyl on physiological mechanisms in wheat and observed that plant has the capacity to counteract the oxidative stress caused by 5-150 µg/kg chlorimuron- ethyl exposure at the first stage, but the capacity is lost with exposure time. Thus, it indicated that the increase of peroxidases activity in the leaves may have been caused by H_2O_2 produced from sources other than SOD (Superoxide dimutases). While, the 300 µg /kg chlorimuron-ethyl treatment caused significant damage to chlorophyll accumulation.

5.3.3 Yield attributing characters

Yield attributing characters *viz.,* effective tillers, ear head length, and number of grains per ear head and test weight were minimum in weedy check plots due to poor growth of crop plants on accounts of heavy infestation of weeds. These yield attributing characters were significantly increased with the adoption of weed control measures. Among the herbicidal treatments, all the yield attributing characters, were maximum when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 g *a.i*. ha^{-1} due to identical reduction in weed growth coupled with no inhibitory effects on wheat crop plant which produced healthy plants by providing stress free environment for the growth and development of crop compared to both lower and higher doses with and without surfactant of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 14.38 and 47.93 g *a.i*. ha^{-1}. Whereas, poor weed control under lowest rate and slight phytotoxic effect of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant under the higher dose 47.93 g *a.i*. ha^{-1} might have produced inferior yield attributes (ear head length, number of grains per ear head and test weight) in comparison to Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 23.96 g *a.i*. ha^{-1}. The number of effective tillers was maximum in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i.* ha^{-1} followed by 19.17 g *a.i*. ha^{-1}. However, all the yield attributing traits were superior in the plots receiving hand weeding (30 and 60 DAS). It might be due to the better control of grassy and broad leaved weeds under hand weeded plots which facilitated healthy plants by providing stress free environment for the growth and development of crop during critical period of crop-weed competition and resulted in superior yield attributes under hand weeding treatment as compared to all the herbicidal treatments including weedy check. Similar observations were also revealed by (Kaur *et al.* 2018, Pal *et al*. 2016, Soltani and Saeedipour. 2015)

Grain yield under particular treatment is the resultant of complex phenomenon, which not only depends on the genetic constitution of the crop plants but also on the production technology adopted therein. Weed caused considerable damage to the crop depending upon the associated weed species, their relative density, duration of crop -weed competition *etc*. and their cumulative effect reflected in terms of reduced crop yield. Weedy plots also had lower grain and straw yields as compared to those plots receiving either manual weeding or herbicidal treatments due to severe competitional stress from crop establishment up to the end of crop growth, leading to poor growth parameters and yield attributing traits and finally the minimum grain and straw yields (Table 4.27).

However, yields were increased appreciably in the plots receiving Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at different doses were applied 14.38 to 23.38 g *a.i*. ha^{-1}, being the maximum when Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant was applied at 23.96 g *a.i*. ha^{-1}. It may be because lower dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant was not very effective in curbing the weed menace, while higher dose of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant 47.93 g *a.i*. ha^{-1} caused slight phytotoxicity on crop plants and thereby produced inferior yield attributing traits leading to lower grain and straw yields. Similarly, Kaur and Brar (2014) also found that grain yield was reduced from 15.8 to 15.6 t ha^{-1} and 16.1 to 14.4 t ha^{-1} with the increase in dose of mesosulfuron + iodosulfuron from 12 to18 g ha^{-1}, respectively. Several studies have demonstrated satisfactory weed control and acceptable crop yields, when herbicides are used at lower than normally recommended doses. Herbicides at reduced doses are often sufficient to control weed density at or below the threshold levels. However, in present study hand weeded plots produced the maximum grain and straw yields but statistically similar to Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i*. ha^{-1} and proved its superiority over other remaining herbicidal treatments. The crop under hand weeded plots attained lush growth due to elimination of all sorts of both grassy and broad leaf weeds from inter and intra rows besides better aeration due to manipulation of surface soil. Thus, more space, water, light and nutrients were available for the better growth and development of crop, which resulted into superior yield attributes and consequently the highest yield This has been supported by Kaur et al. (2017), Chaudhary et al. (2017), Sasode *et al.* (2017) and Barla *et al.* (2017), also reported that hand weeding was an effective method of weed control for achieving the maximum yield of wheat.

Harvest index was significantly affected due to weed control treatments during both the years. The maximum harvest index was recorded in hand weeding twice plot (42.6) closely followed by Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with surfactant at 23.96 g *a.i*. ha^{-1} (42.4) and minimum harvest index recorded under weedy check (39.1). It may possible due to lesser weed population under these plots. These results are in agreement with Kumar *et al*. (2005), who reported that the effective weed control created favorable conditions for batter growth of crop and increased NPK availability resulting increase harvest index of wheat crop.

4.3.4 Quality parameter

Protein content in grain was significantly affected due to weed control treatments during both the years (Table 4.29). The higher protein content was recorded under hand weeding twice 30 and 60 DAS (12.14 %) whereas, the lower protein content was recorded under weedy check (11.63 %) which was increased when weed control measures were adopted. Post emergence application of Halauxifen – methyl 6.95 % + Pyroxsulam 25 % with and without surfactant at all doses 14.38, 19.17 and 23.96 g *a.i*. ha^{-1} (11.82 and 11.68 %, respectively) were statistically similar in terms of protein content and proved significantly superior over unweeded check (11.63 %).The higher protein content could be ascribed to higher N assimilation in absence of competition in weed control treatments. This has been supported by Kumar *et al*. (2005) and Pandey *et al*. (2006).

5.3.5 Effect on nutrient uptake

5.3.6 Effect of weed control practices

Marked influence of weed control treatments was observed on N, P and K uptake by grain and straw of wheat crop. Weedy check registered minimum uptake of N, P and K where weed control measures were not adopted, due to the increase in weed dry matter accumulation. The similar results have been reported by Pandey *et al.* (2001). Weed control practices done either chemically or manually caused identical increase in nutrient uptake. This was due to quantitatively higher dry matter production in comparison to weedy check because of enhanced nutrients, water, space and light supply to the wheat crop on account of less crop-weed competition. However, the post emergence application of Halauxifen – methyl 6.95% + Pyroxsuma 25 % with and without surfactant at lower dose 14.38 g *a.i*. ha^{-1} caused appreciably increase in N, P and K uptake over weedy check plots which was further increased when Halauxifen – methyl 6.95% + Pyroxsuma 25 % with surfactant was applied at medium dose 19.17 g *a.i.* ha^{-1} but thereafter with the increase in dose with surfactant from 23.96 g *a.i*. ha^{-1}, slightly decrease in uptake noticed. However, hand weeding twice caused maximum increase in uptake of N, P and K by grain and straw. Study of Singh *et al.* (2009) revealed that the plot receiving hand weeding twice at 30 and 45 DAS were recorded maximum N, P and K uptake by wheat.

5.3.7 Economic Viability of Treatments

The determination of economics is the most important to evaluate the effect of treatments from farmers as well as planners point of view. The main aim of the farmers is to earn more profit per unit area per unit time in relation to per unit of investment. The economic analysis of particular treatment consisted of cost of cultivation, gross monetary returns (GMRs), net monetary returns (NMRs) on per hectare basis and benefit-cost ratio. Therefore, economic analysis of the treatments gives valuable information for both grower and planners as well. The economic analysis discussed here by considering the cost of inputs used and values of produce obtained during the course of investigation.

Cost of cultivation (₹ ha^{-1})

The analysis of cost of cultivation is important because it decides the option for the farmers to choose the production practices, according to their investment capacity. The cost of cultivation to grow the wheat crop under each treatment was determined on the basis of cost involved for common agro-input used in the field operations with variable inputs and operations used as per treatments on per hectare area basis. It was clear from the data on cost of cultivation (Table 42 and Appendix XIII) that the cost was varying due to different herbicidal treatments. The data showed that plots receiving hand weeding twice at 30 and 60 DAS, required maximum variable cost (6000 ₹ ha^{-1}), which was not affordable by the poor farmers and at the same time the availability of laboures during peak period is also not certain. All the herbicidal treatments receiving application of Halauxifen – methyl 6.95% + Pyroxsuma 25 % needed less variable cost (1095-2670 ₹ ha^{-1}) over hand weeding twice. Thus, use of Halauxifen – methyl 6.95% + Pyroxsuma 25 % for control of weeds seems to be cheaper from farmers view point in areas where availability of manual labours is not assured and wages are higher.

Gross monetary returns (₹ ha^{-1})

Gross monetary returns (GMRs) under different treatments was determined on the basis of value of main and by product obtained from wheat crop under particular treatment. It was obvious from two years mean data that the gross monetary returns (GMR) was minimum (64850 ₹ ha^{-1}) under weedy check because of the lowest grain and straw yields (Table 42). But, it was increased appreciably with the adoption of weed control measures the gross monetary returns positively correlated with the yields and economic value of crop. Among the herbicidal treatments in combination with and without surfactant those plots receiving 23.96 g *a.i.* ha^{-1} Halauxifen – methyl 6.95% + Pyroxsuma 25 % with surfactant fetched the higher GMR (96716 ₹ ha^{-1}). It might be due to higher yields of component crops with application of 23.96 g a.i. ha^{-1} Halauxifen – methyl 6.95% + Pyroxsuma 25% with surfactant in comparison to remaining herbicidal treatments. It caused weed free environment and assured better supply of growth resources to wheat crop and finally recorded high grain and straw yields. Henceforth, this treatment fetched higher gross monetary returns. However, the GMR was maximum (98629 ₹ ha^{-1}) under hand weeded plots when hand weeding was done due to excellent growth, yield attributing traits and yields on account of weed free environment during critical period of crop growth.

Net monetary returns (₹ ha^{-1})

The net monetary returns (NMR) per unit area are actual monetary gain under a particular treatment because it was determined by subtracting the cost of cultivation from gross monetary returns (GMR) of the same treatment. The treatment wise values, thus obtained, are given in Table 42. It was obvious from the mean data that NMR was minimum (33802 ₹ ha^{-1}) in weedy check plot when crop was not weeded throughout the crop season which increased remarkably under all the plots receiving weed control measures. However, post emergence application of Halauxifen – methyl 6.95% + Pyroxsuma 25 % with surfactant at 23.96 g *a.i.* ha^{-1} was more profitable than any other weed control treatments which fetched the highest value of NMR (64123 ₹ ha^{-1}) followed by hand weeding twice done (61581₹ ha^{-1}). Comparatively lower variable cost (1296 ₹ ha^{-1}) under Halauxifen – methyl 6.95% + Pyroxsuma 25 % without surfactant 23.96 g a.i. ha^{-1} applied as post-emergence coupled with higher grain and straw yields might be the reason for higher NMR over all other herbicidal treatments. Though hand weeded plots had maximum GMR, even than it proved inferior to latter treatment due to five times higher variable cost (6000 ₹ ha^{-1}) under hand weeding treatment. The similar results have been reported by Saini and Walia (2010), Sharma *et al.* (2015) and Chaudhary *et al.* (2008)

Benefit - cost ratio

The benefit-cost ratio of a particular treatment is said to be actual monetary gain over each rupee of investment (Table 4.33). The data on benefit-cost ratio showed that the minimum B:C ratio obtained when no weed control was adopted in weedy check plots (2.1). But profitability was increased appreciably with the adoption of weed control practices and day time applications. However, the maximum B:C ratio (3.0) was registered under the plots receiving post emergence application of Halauxifen – methyl 6.95% + Pyroxsuma 25% with surfactant at 23.96 g *a.i.* ha^{-1}. the minimum under hand weeded plots among the all weed control measures. It might be due to inappropriate increase in benefit per rupee of investment under hand weeded plots. This has been supported by Sasode, *et al.* (2017) revealed that, highest B:C ratio of (3.69) was obtained with Pinoxaden + Metsulfuron (pre-mix) followed by Sulfosulfuron + Metsulfuron (3.67). Sharma *et al.* (2015) and Jain *et al.* (2007).

5.4 Carryover effect on succeeding crops

The carry over effect of different herbicides applied in wheat crop was found non-significant on germination (10 DAS), plant population (15 DAS and at harvest) and yield attributing characteristics *viz.,* (branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed index) and seed yield, straw yield and harvest index production of succeeding soybean crop (Tables 4.22 to 4.26). The results clearly indicated that different herbicides viz. (T_1) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 14.38 g *a.i.* ha^{-1}, (T_2) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 19.17 g *a.i.* ha^{-1}, (T_3)

Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 23.96 g *a.i.* ha^{-1}, (T_4) Halauxifen – methyl 6.95% + Pyroxsulam 25% + 14.38 g *a.i.* ha^{-1}, (T_5) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 19.17 g *a.i.* ha^{-1}, (T_6) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 23.96 g *a.i.* ha^{-1}, (T_7) Pyroxsulam 4.5 % with surfactant 18.75 g *a.i.* ha^{-1} , (T_8) Halauxifen – methyl 10.42 % with surfactant 5.21 g *a.i.* ha^{-1}, (T_9) Sulfosulfuron + Metsulfuron – methyl with surfactant 32 g *a.i.* ha^{-1} , (T_{10}) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 47.93 g *a.i.* ha^{-1}, did not left their residual phytotoxic effect in the soil after harvesting wheat crop on succeeding soybean crop. Sharma and Angiras (1996) observed that the residue of pendimethalin 1.5 kg ha^{-1} pre-emergence applied in wheat was only 0.001 ppm in soil after harvest of wheat through bioassay using oat as indicator plant. Singh and Ali (2004) found that post-emergence. Application of metsulfuron methyl at 3 to 5 g ha^{-1} and 2,4-D 0.75 kg ha^{-1} did not leave any residual toxicity to the succeeding soybean crop. Yadav *et al.* (2004) studied residual impact of various herbicides applied in wheat on succeeding *kharif* season crops and reported that metsulfuron (4 and 8 g ha^{-1}), 2,4-D (0.5 & 1 kg ha^{-1}), isoproturon (1 kg ha^{-1}) and pendimethalin (1.5 kg ha^{-1}) applied in wheat did not exhibit any adverse effect on mungbean, maize, cowpea, pigeonpea, pearlmillet and cotton.

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

Wheat is one of the most important staple food grains for human beings. It is the most commonly and widely grown crop in India including Madhya Pradesh under irrigated conditions. India is the second largest producer of wheat in the world, the total area under wheat in the world is around 219.61 million ha with a production of 729.1 million tonnes. In India wheat is grown in an area of about 29.58 million hectares with the production of 99.70 million tonnes and the productivity of 33.71 q ha^{-1}. In Madhya Pradesh, it is grown in 5.56 million ha area with the production of 15.9 million tonnes and share in all India production 15.96 %.

Introduction of semi dwarf varieties of wheat coupled with increased use of fertilizers and irrigation provides congenial growth conditions for weeds. Slow initial growth of wheat and high fertilization during the successive growth period encourage the rapid growth of weeds, making the problem more serious and if weeds were not controlled in time, they cause substantial reduction in yield. Hand weeding is widely practiced to control weeds, but it is costly and time consuming. Hence, chemical weed control has become common practice since last two decades and the use of Sulfosulfuron in very common for control of *Phalaris minor* in wheat. But due to development of resistance in *Phalaris minor* weed shift in the cropped area, there is an urgent need to find out alternate herbicides, which can take care of weeds in wheat crop. Keeping this fact in mind, the present investigation was taken under entitled **"Evaluation of halauxifen – methyl 6.95% + pyroxsulam 25% ready mixture efficacy against weed flora in wheat**" at Research Farm, Department of Agronomy, College of Agriculture, Jabalpur, JNKW, Jabalpur, M.P. during the *Rabi* seasons of 2016-17 and 2017-18 on clay loam in texture, neutral in reaction (pH 7.20), medium in organic carbon content (0.54 %), normal in electrical conductivity (0.29 dsm^{-1}), medium in available N (260.12 kg ha^{-1}), P (12.25 kg ha^{-1}) and high in available K (295.10 kg ha^{-1}).Twelve treatments consisted with ten herbicidal treatments as post emergence application of (T_1) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 14.38 g *a.i.* ha^{-1}, (T_2) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 19.17 g *a.i.* ha^{-1}, (T_3) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 23.96 g *a.i.* ha^{-1}, (T_4) Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant 14.38 g *a.i.* ha^{-1}, (T_5) Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant 19.17 g *a.i.* ha^{-1}, (T_6) Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant 23.96 g *a.i.* ha^{-1}, (T_7) Pyroxsulam 4.5 % with surfactant 18.75 g *a.i.* ha^{-1} , (T_8) Halauxifen – methyl 10.42 % with surfactant 5.21 g *a.i.* ha^{-1}, (T_9) Sulfosulfuron + Metsulfuron – methyl with surfactant 32 g *a.i.* ha^{-1} , (T_{10}) Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 47.93 g *a.i.* ha^{-1}, (T_{11}) hand weeding twice (30 and 60 DAS) and (T_{12}) Unweeded check (Weedy check) were tested in randomized block design with three replications. Sowing of the experiment was done on (first year) 29 Nov. 2016 and harvested on 30 March 2017, in second year crop was sown 25 Nov. 2017 and harvest at 31 March 2018 in the plot sixe 5.00 m x 3.15 m with seed rate 100 kg ha^{-1} by drilling in rows 22.5 cm apart. A uniform dose of 120 kg N, 60 kg P_20_5 and 40 kg K_20 kg ha^{-1} was given through urea, single super phosphate and muriate of potash, respectively, in all plots. At the time of sowing of wheat seed, 60 kg N dose and full dose of P_2O_5 and K_2O was applied as basal dose. Top dressing of 30 kg N dose was applied at 30 days after sowing and 30 kg at 50 days after sowing (at panicle initiation). Crop was irrigated uniformly under all plots.

Weed control was done as per treatments. Different studies were made during the course of investigation pertaining to weed and crop parameters. Dominant weed flora and their species wise density were recorded under all treatments at different growth stages of crop. Plant population at initial and at harvest stage and growth parameters *viz*. plant height, number of tillers, leaf area, leaf area index, dry mater accumulation, chlorophyll content were recorded at 30, 60, 90, DAS and at harvest stages. Yield attributing characters *viz*., effective tillers m^{-1} row length, length of ear head (cm), grains ear $head^{-1}$ and test weight (g) were recorded at harvest. Finally grains and straw yields were recorded treatment wise. Weed control efficiency, weed index, harvest index and economic viability of treatments were also determined from the data generated and the results interpreted in previous chapter are being summarized below.

6.2 Weed flora in wheat

Species wise weed flora was recorded in weedy check plots indicated that there was pre-dominance of dicot weeds (88.1 and 88.3%) as compared to monocot weeds (11.9 and 11.7%) in the experimental field during both years *i.e.* 2016-17 and 2017-18, respectively. Among the dicot weeds, *Medicago denticulata* was more rampant constituting 28.9 and 229.9 % relative density, followed by *Medicago truncatula* (23.3 and 21.1 %), whereas, *Cyperus iria* was dominant the monocots (11.9 and 11.7 %). However, other dicot weeds like *Chenopodium album*, *Anagallis arvensis* and *Cichorium intybus* also marked their presence in good numbers in wheat.

6.3 Effect on growth, yield attributes and yields of wheat

In general, poor values of crop growth parameters (plant height, number of tillers, crop biomass, leaf area index, crop growth rate and relative growth rate) and yield attributing characters (effective tillers, ear head length, number of grains per ear head and test weight) were recorded in weedy check which in turn resulted into lower grain as well as straw yields of wheat followed by highest dose of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant 47.93 g *a.i.* ha^{-1}. However, the values of all crop growth parameters and yield attributing characters were increased appreciably when weed control measures were adopted. Application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at lower dose 14.38 g *a.i.* ha^{-1} caused appreciable increase in all the growth parameters and yield attributing characters including yields being higher when it was applied at higher dose 23.96 g *a.i.* ha^{-1} with surfactant. However, all the growth parameters and yield attributing characters of crop were considerably superior under hand weeded plots compared to rest of the treatments and ultimately produced the maximum grain as well as straw yield. Among the herbicidal treatment, post emergence application of Halauxifen – methyl 6.95% + Pyroxsulam 25% at different doses with and without surfactant had significantly higher grain yield over weedy check. However, plots receiving hand weeding (30 and 60 DAS) produced maximum grain and straw yields being at par to application Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at higher dose 23.96 g *a.i.* ha^{-1}.

6.4 Nutrient uptake

By grain

Weed control treatments had marked influence on nitrogen, phosphorus and potassium uptake by grain of wheat. Weedy check plots had minimum uptake of N, P and K by grain. However, uptake was increased appreciably in plots receiving Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at 14.38 g *a.i.* ha^{-1} and it was further increased when Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant was applied at higher dose 23.96 g *a.i.* ha^{-1} and proved significantly superior over application of other herbicidal treatments and weedy check plots. However, maximum uptake of N, P and K by grain was recorded in the plots receiving hand weeding treatment and proved significantly superior over all other treatments.

By straw

All the weed control measures registered significantly higher N, P and K uptake over weedy check. Hand weeding had maximum uptake followed by application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at 23.96 g *a.i.* ha^{-1}. However, numerically higher uptake was observed when Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant were applied.

6.5 Economic viability of treatments

Hand weeding needed an investment of 36648 ₹ ha^{-1} to control weeds, while, expenditure incurred under herbicidal treatments ranged from 32143 to 33718 ₹ ha^{-1}, indicating that hand weeding was more expensive practice than use of herbicide to control the weeds in wheat crop. Among the herbicidal treatments in combination with and without surfactant, the plots receiving Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at 23.96 g *a.i.* ha^{-1} fetched higher GMR (96716 ₹ ha^{-1}) closely followed by application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at 19.17 g *a.i.* ha^{-1} (93111 ₹ ha^{-1}, respectively) and proved better over other herbicidal combinations. Though, the GMR was maximum (98629 ₹ ha^{-1}) under hand weeding (30 and 60 DAS). Application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at

23.96 g *a.i.* ha^{-1} was more profitable than any other weed control treatments as it fetched the highest value of NMR (64123 ₹ ha^{-1}) followed by hand weeding (61981 ₹ ha^{-1}). The benefit per rupee of investment was more under post emergence application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at 23.96 g *a.i.* ha^{-1} (3.0) over other treatment combinations even to hand weeding done at different time.

6.6 Conclusions

Based on the foregoing discussion, the following conclusions could be drawn

1. Dicot weeds *i.e*. *Medicago denticulata* (28.9 and 29.9 %) and *Medicago truncatula* (23.3 and 21.1 %) were predominant weeds in wheat during 2016-17 and 2017-18, respectively. However, other dicot weeds *viz*., *Chenopodium album* (14.0 and 14.2 %), *Anagallis arvensis* (11.1 and 12.0 %), *Cichorium intybus* (10.8 and 11.1 %) and monocot weed *cyperus iria* (11.9 and 11.7 %, respectively) also marked their presence in good numbers.
2. Post - emergence application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant @ 23.96 g *a.i.* ha^{-1} significantly lowered the weed density and weed biomass.
3. Application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant @ 23.96 g *a.i.* ha^{-1} attained the superior values of crop growth parameters (plant height, crop dry weight, leaf area index, crop growth rate, relative growth rate), yield attributes (effective tillers, length of earhead, grain earhead^{-1}, test weight), grain and straw yield.
4. There was no phytotoxicity on succeeding soybean crop after application of herbicidal treatments on preceding wheat crop.
5. Application of Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant @ 23.96 g *a.i.* ha^{-1} fetched higher net monetary returns (64123 ₹ ha^{-1}) and benefit cost ratio (3.0)

6.7 Suggestions for Further Work

1. Halauxifen – methyl + Pyroxsulam should also be tested with other compatible herbicides at different doses in wheat crop so as to get effective control of grassy as well as broad leaved weeds.
2. Similar studies should also be carried out in different soil types, varieties and herbicides.
3. The residual effects of herbicides in soil, plants and seeds are to be assessed to decide the sustainable use of herbicidal treatments over the years.
4. Studies pertaining to weed dynamics and changes in soil physicochemical properties need to be confirmed with the repetition of present investigation for at least 3 years.
5. The experiment needs to be tested on other agro-climatic conditions of M.P. for at least 2-3 years to confirm the present findings.

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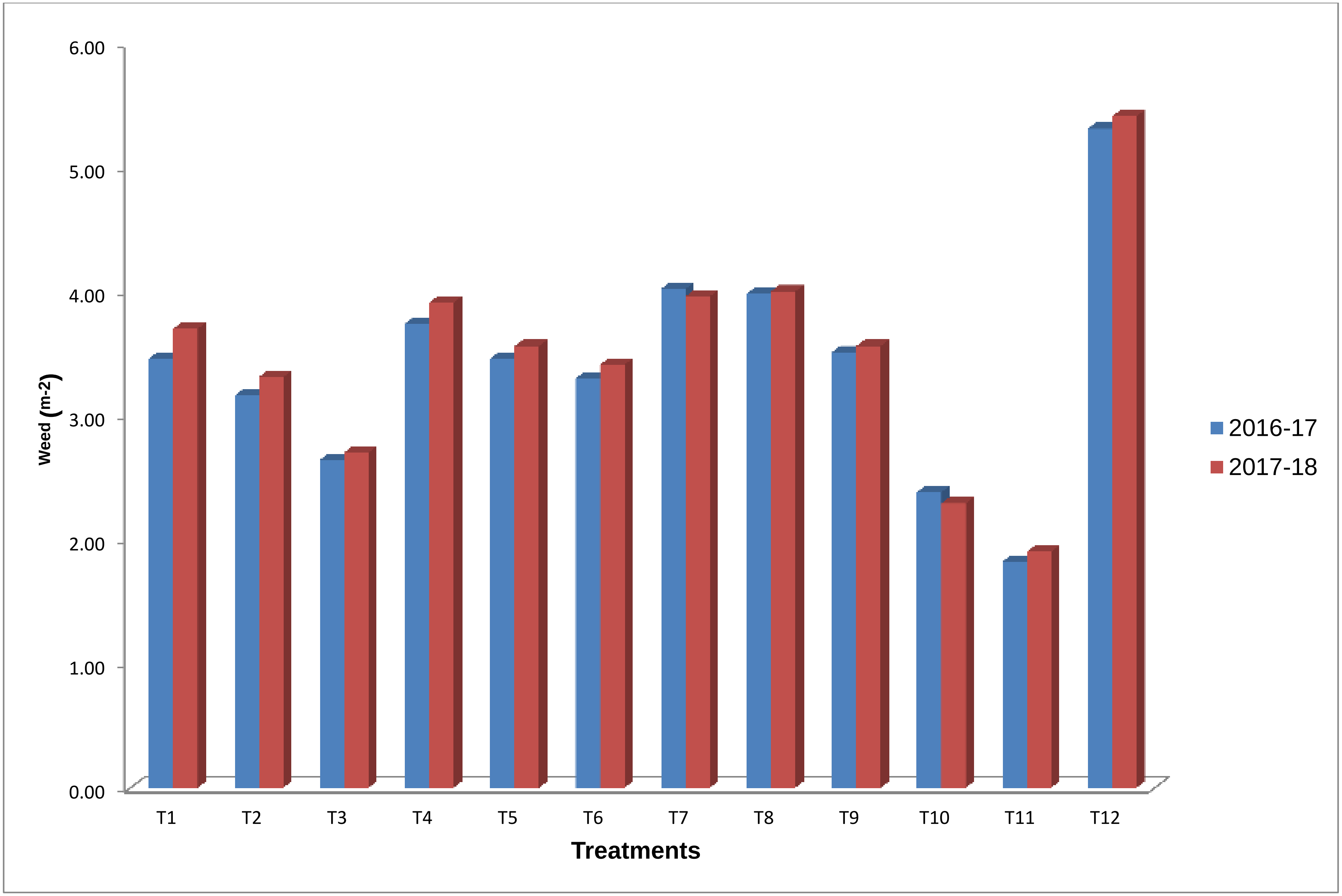

Fig. 4.2 Effect of different herbicidal treatments on density of *Cyperus iria* (m^{-2}) in wheat at 30 days after application

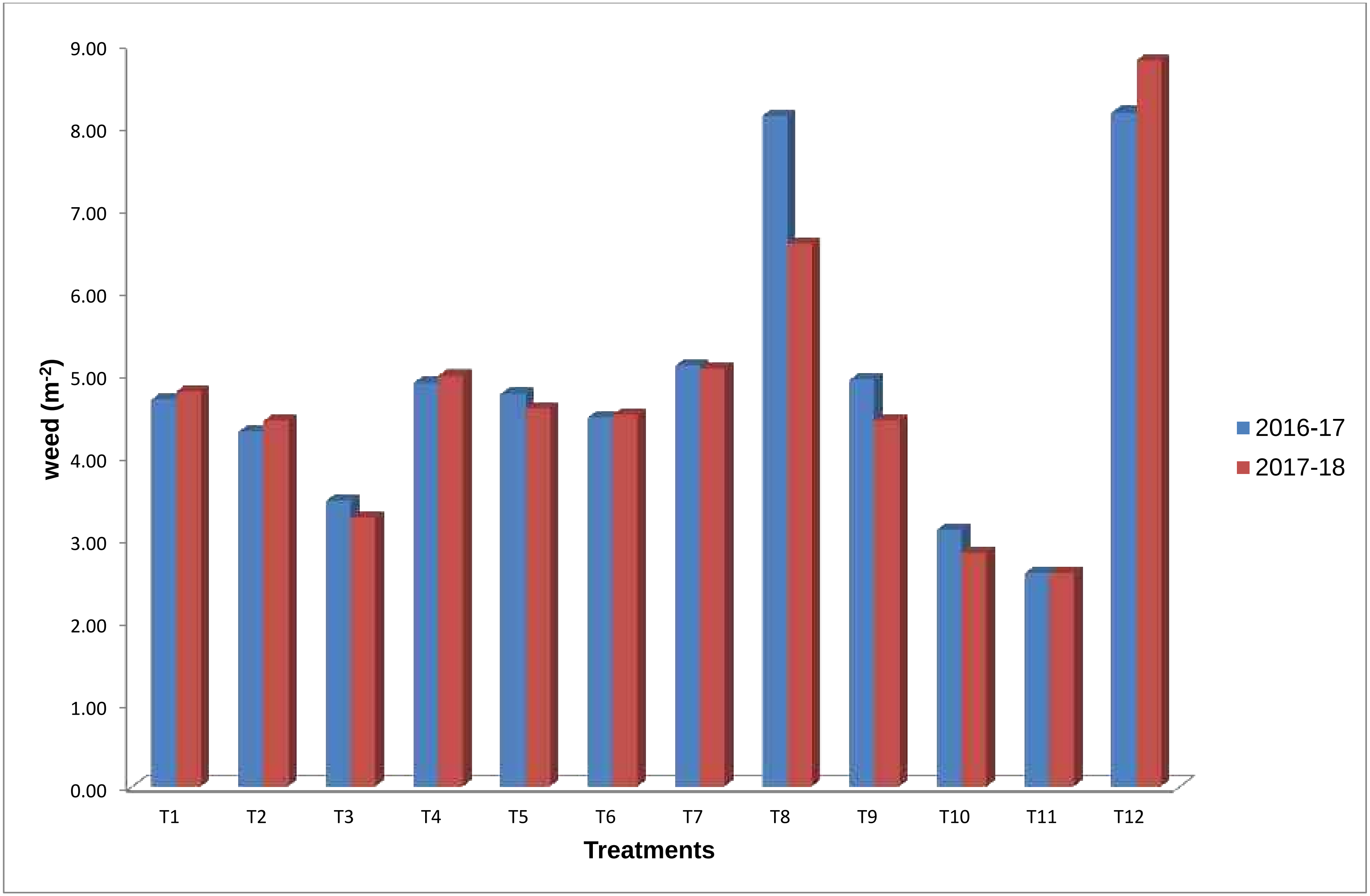

Fig. 4.3 Effect of different herbicidal treatments on density of *Medicago denticulata* (m^{-2}) in wheat at 30 days after application

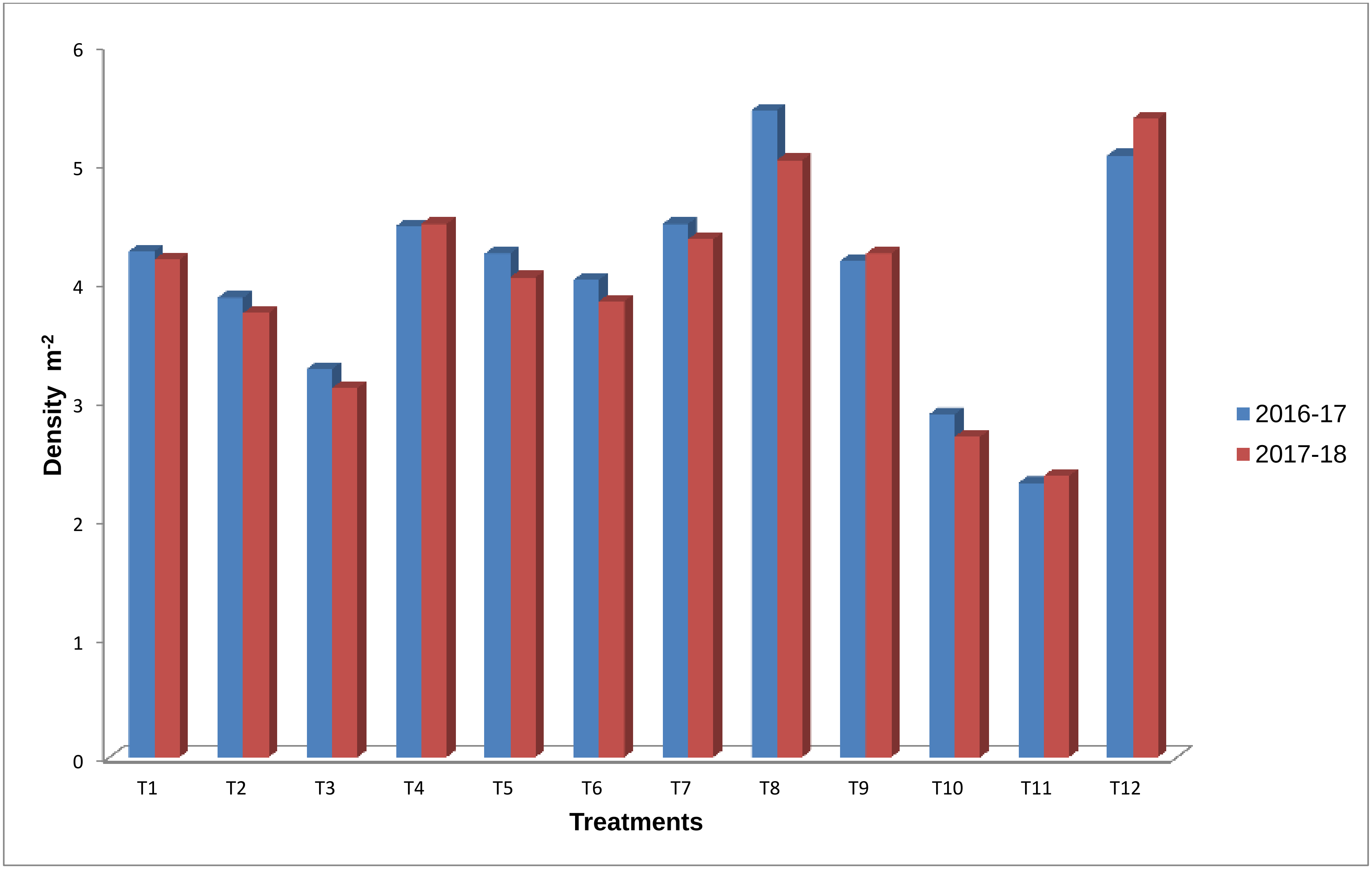

Fig. 4.4. Effect of different herbicidal treatments on density of *cichorium intybus* (m^{-2}) in wheat at 30 days after application

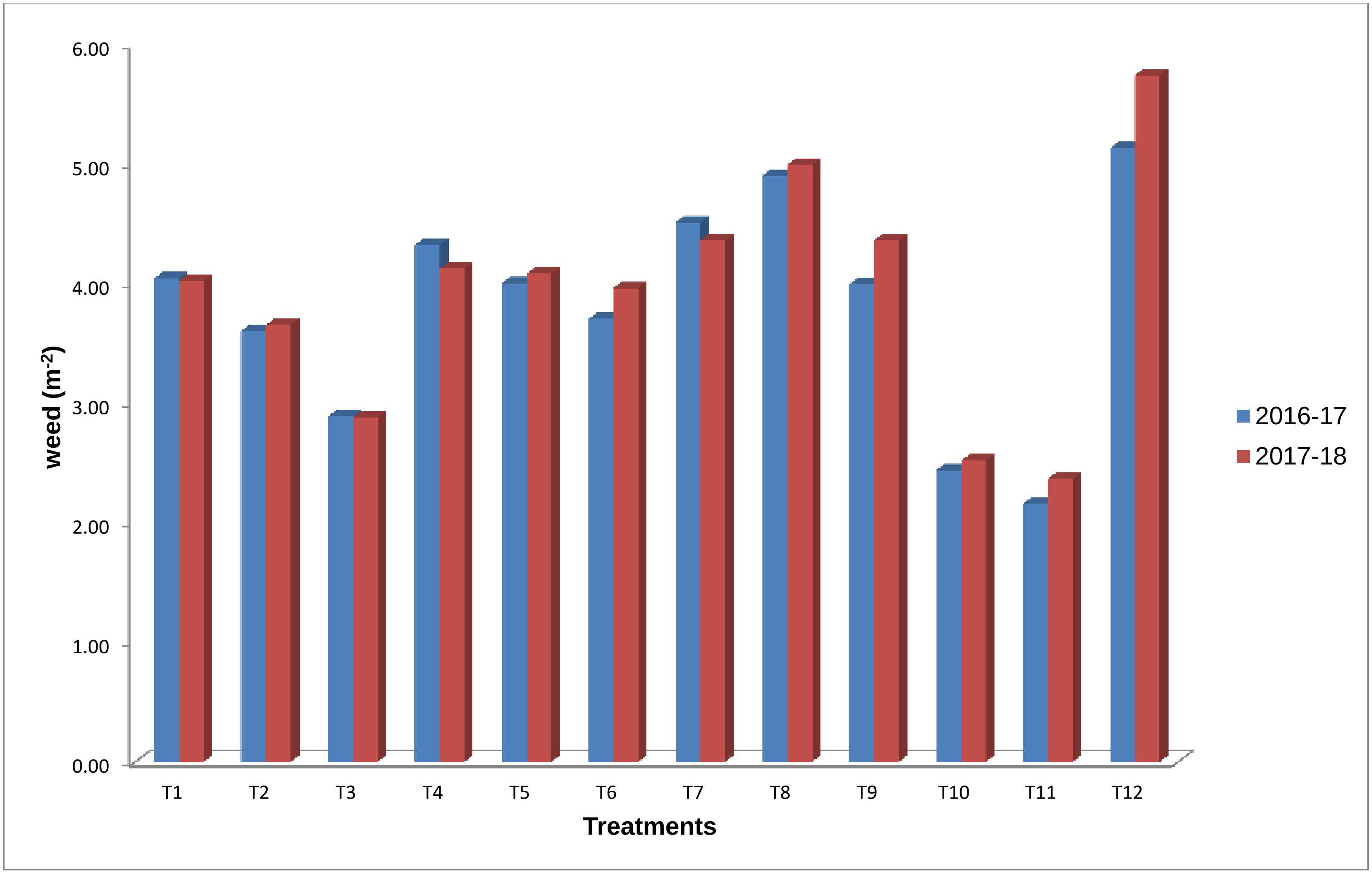

Fig. 4.5. Effect of different herbicidal treatments on density of *Anagallis arvensis* (m^{-2}) in wheat at 30 days after application

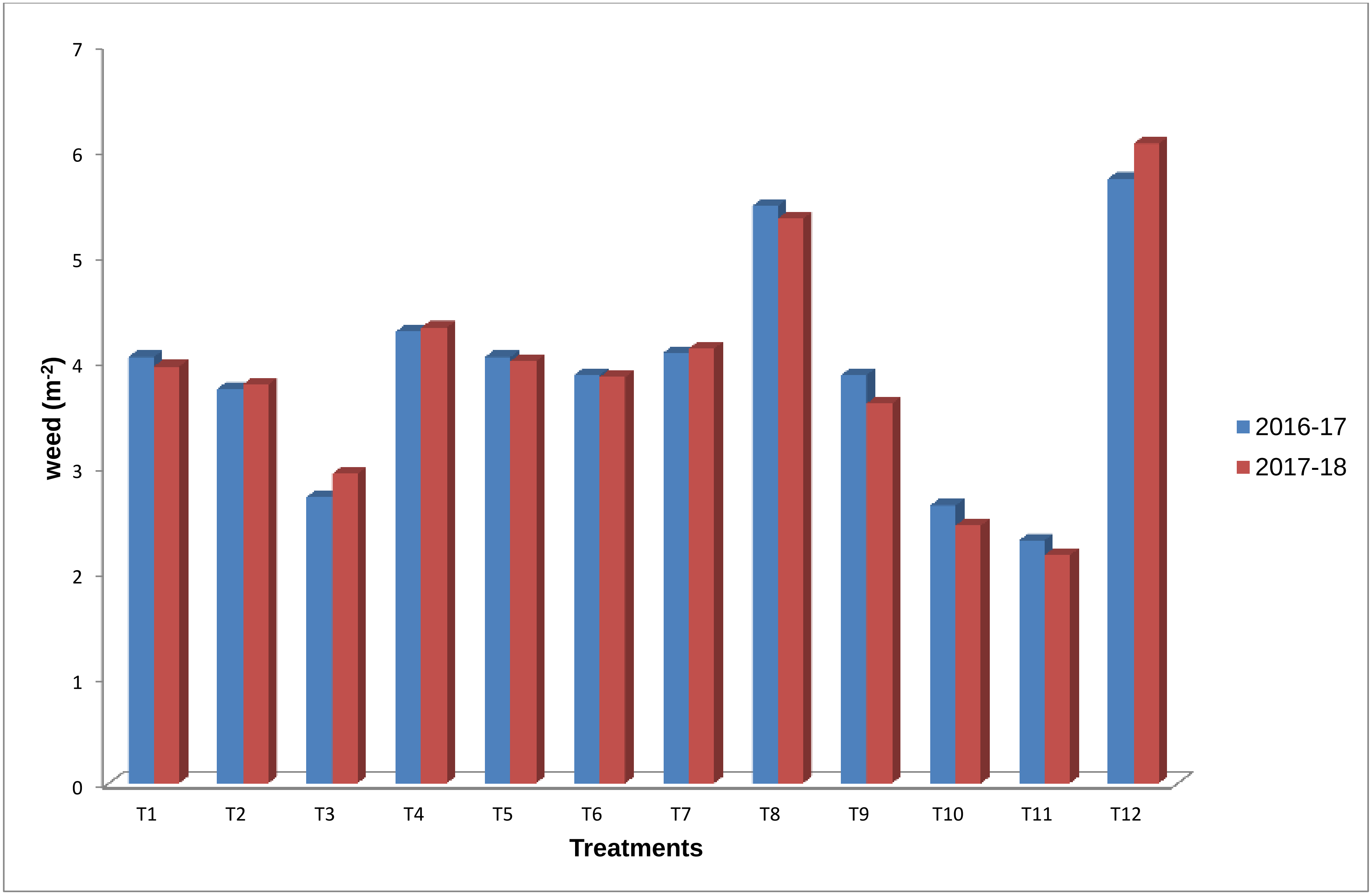

Fig. 4.6. Effect of different herbicidal treatments on density of *Chenopodium album* (m^{-2}) in wheat at 30 days after application

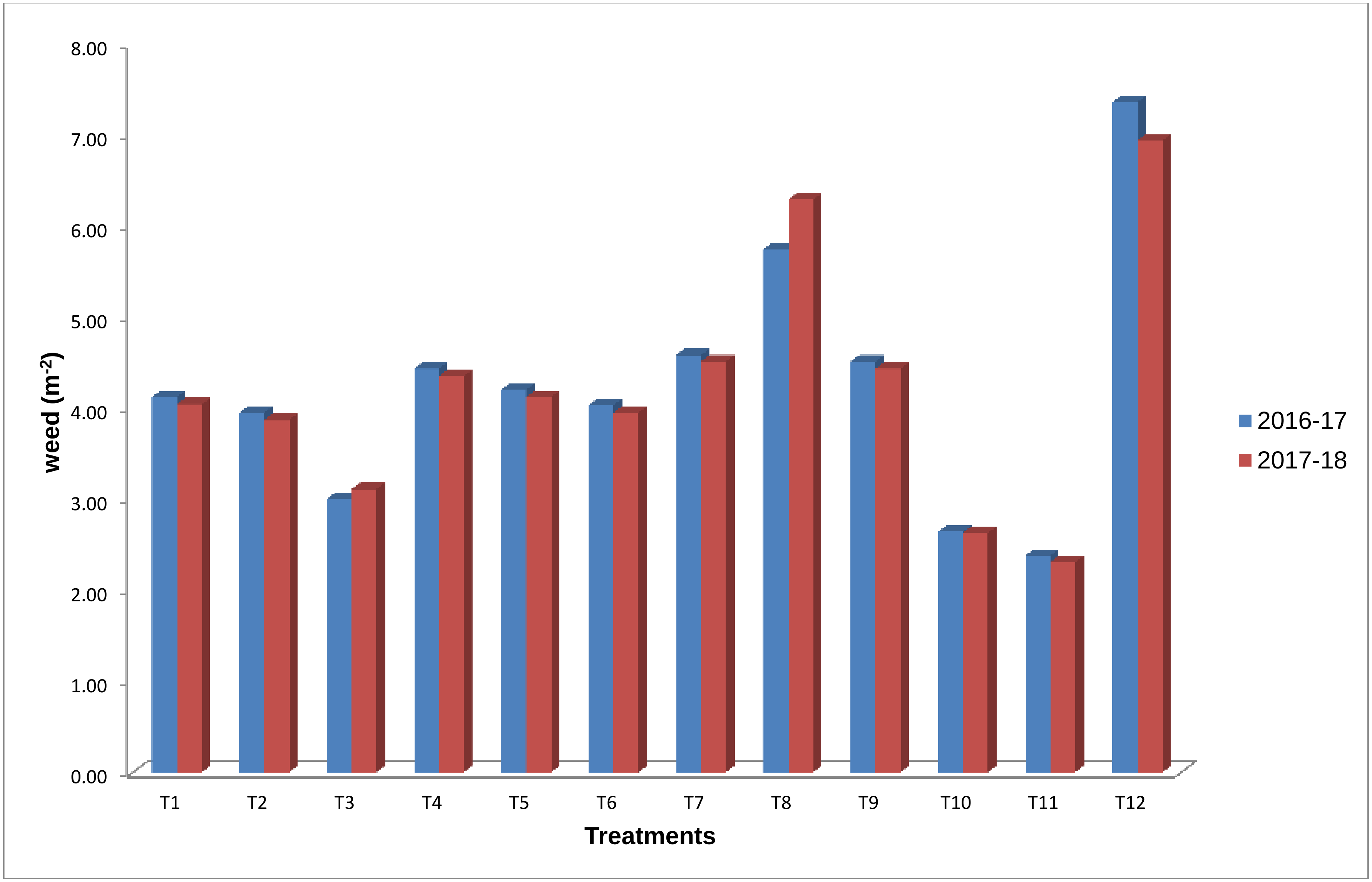

Fig. 4.7. Effect of different herbicidal treatments on density of *Medicago truncatula* (m^2) in wheat at 30 days after application

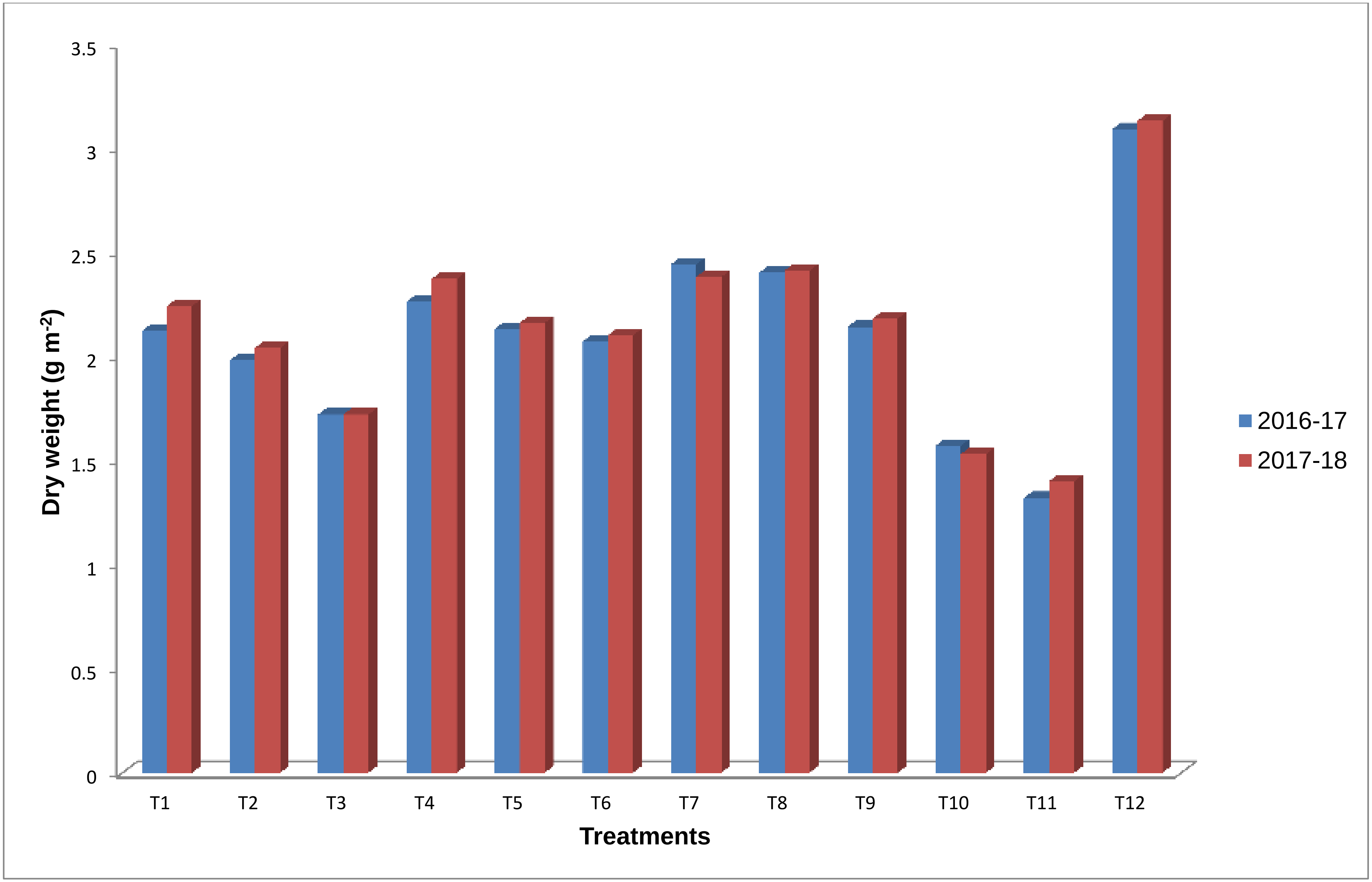

Fig. 4.8. Effect of different herbicidal treatments on dry weight of *Cyperus iria* (gm^{-2}) in wheat at 30 days after application

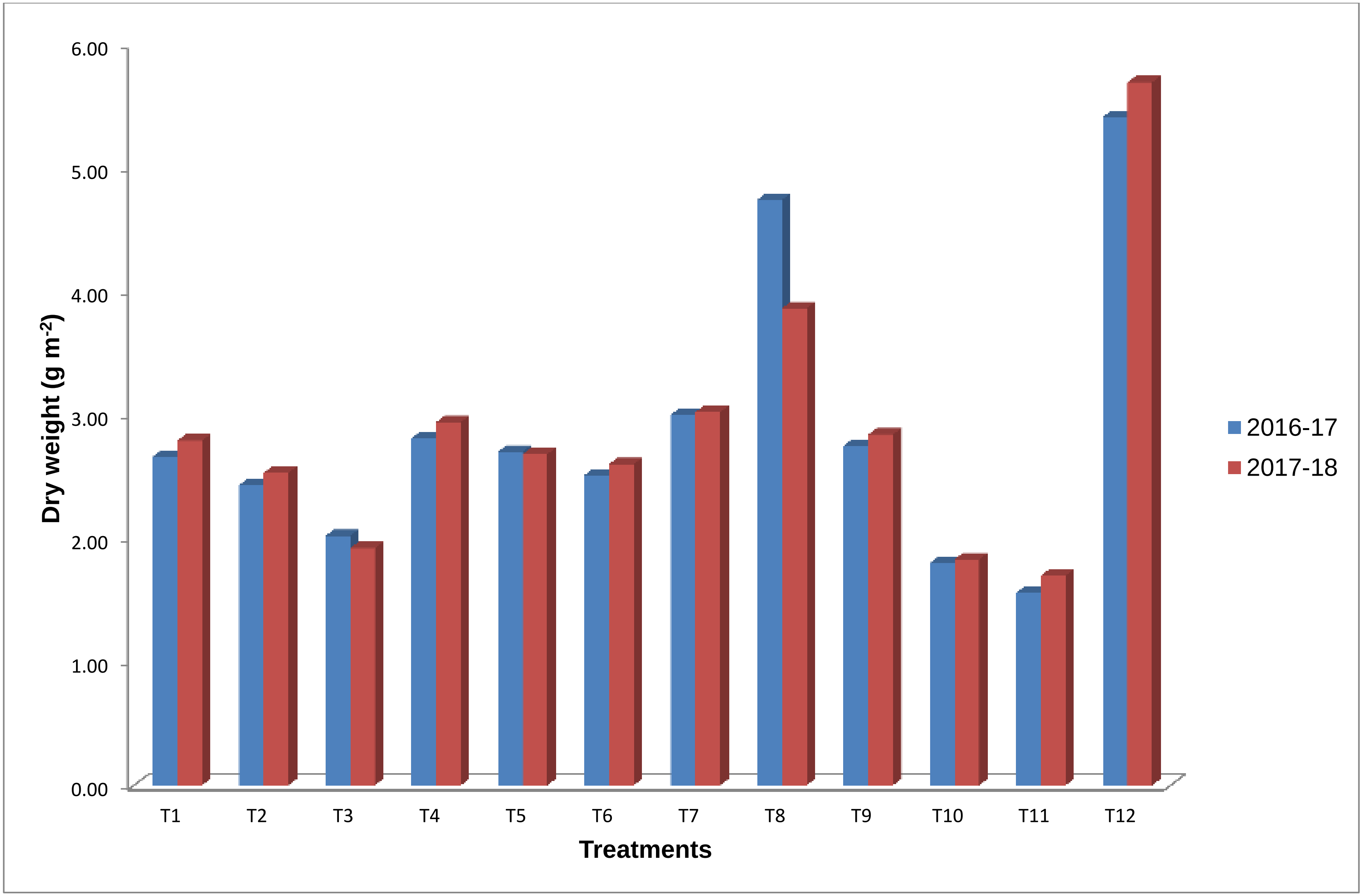

Fig. 4.19. Effect of different herbicidal treatments on dry weight of *Medicago denticulata* (gm^{-2}) in wheat at 30 days after application

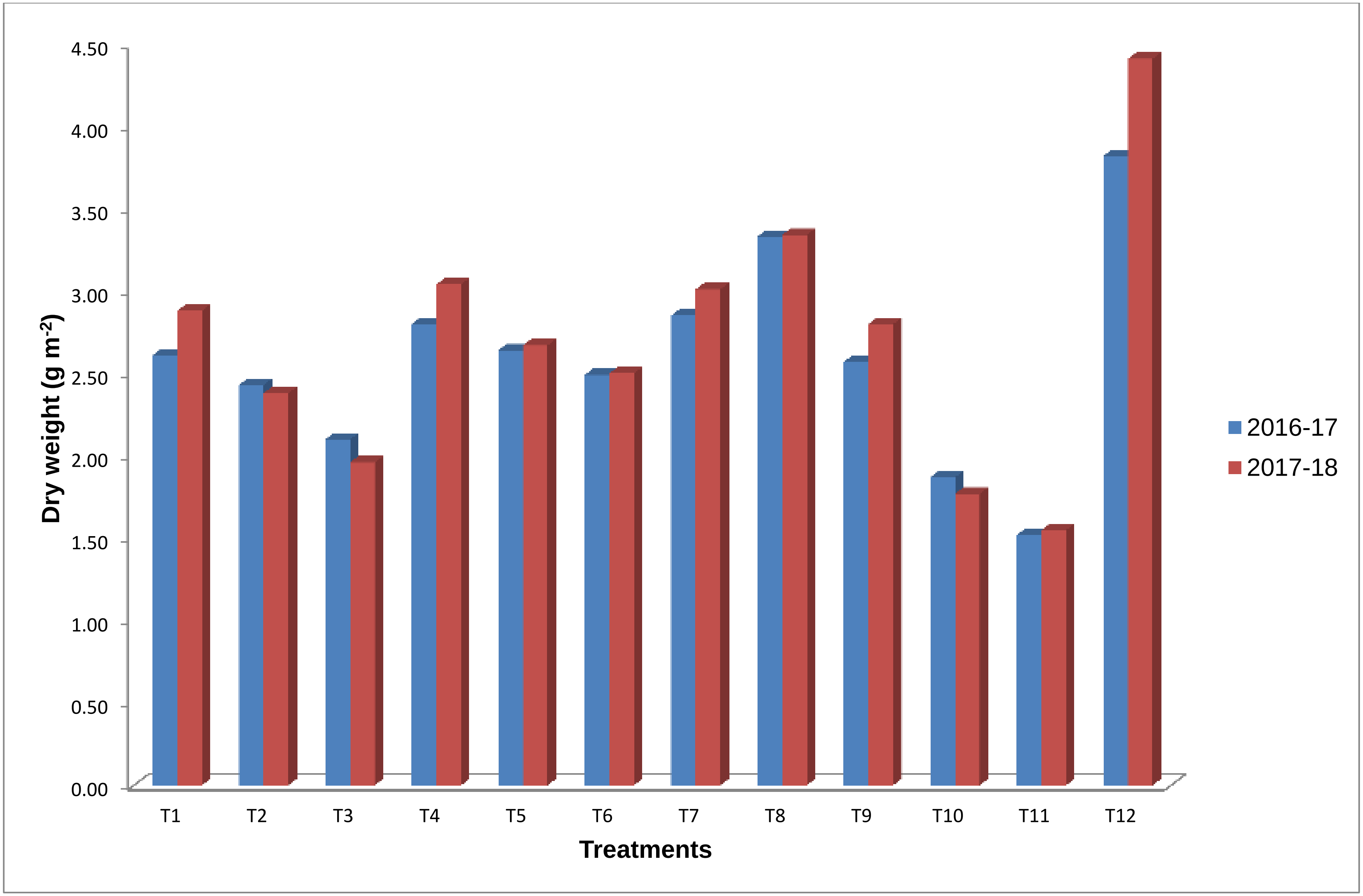

Fig.4.10. Effect of different herbicidal treatments on dry weight of *Cichorium intybus* (g m^{-2}) in wheat at 30 days after application

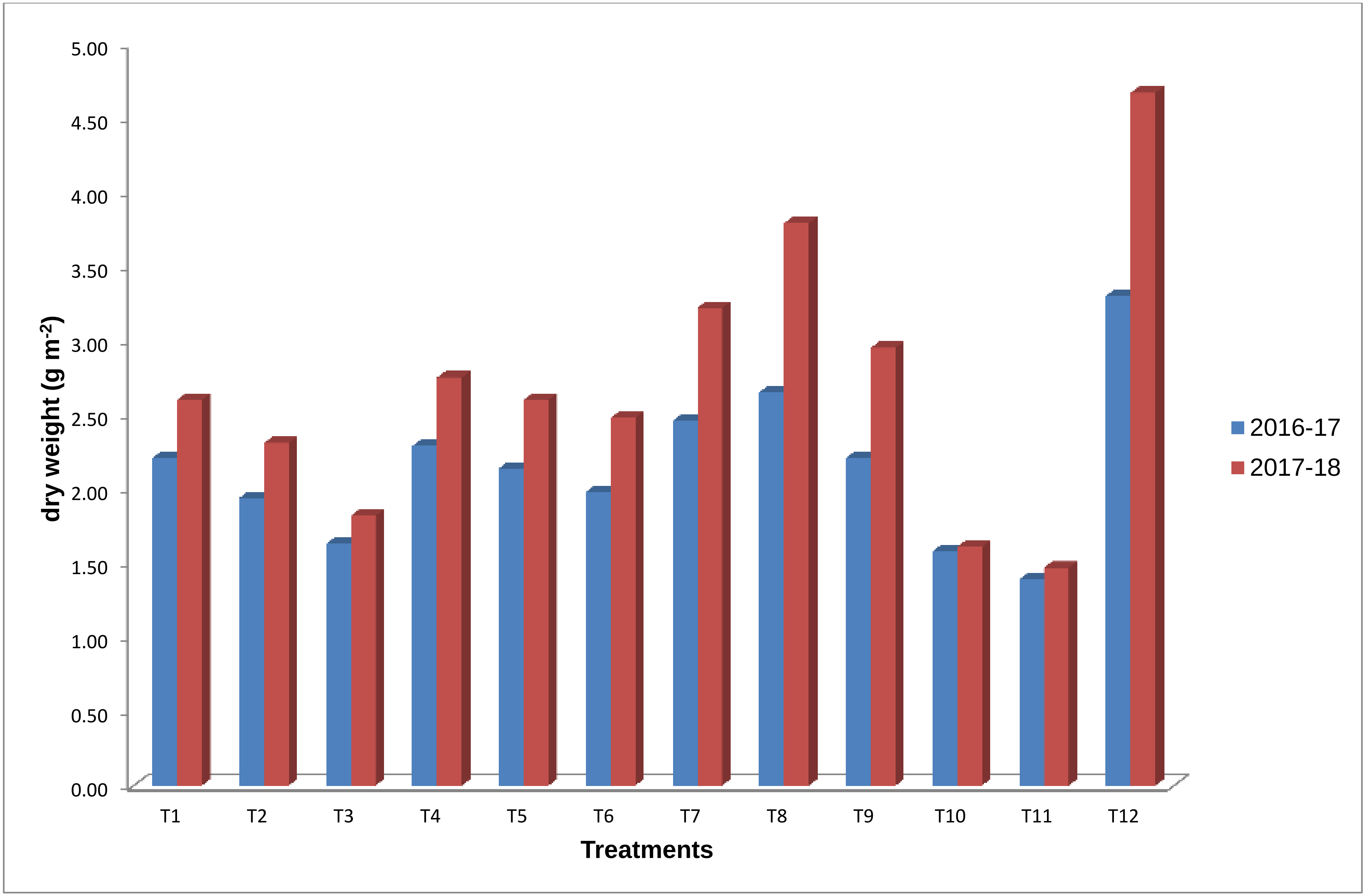

Fig. 4.11. Effect of different herbicidal treatments on dry weight of *Anagallis arvensis* (g m^{-2}) in wheat at 30 days after application

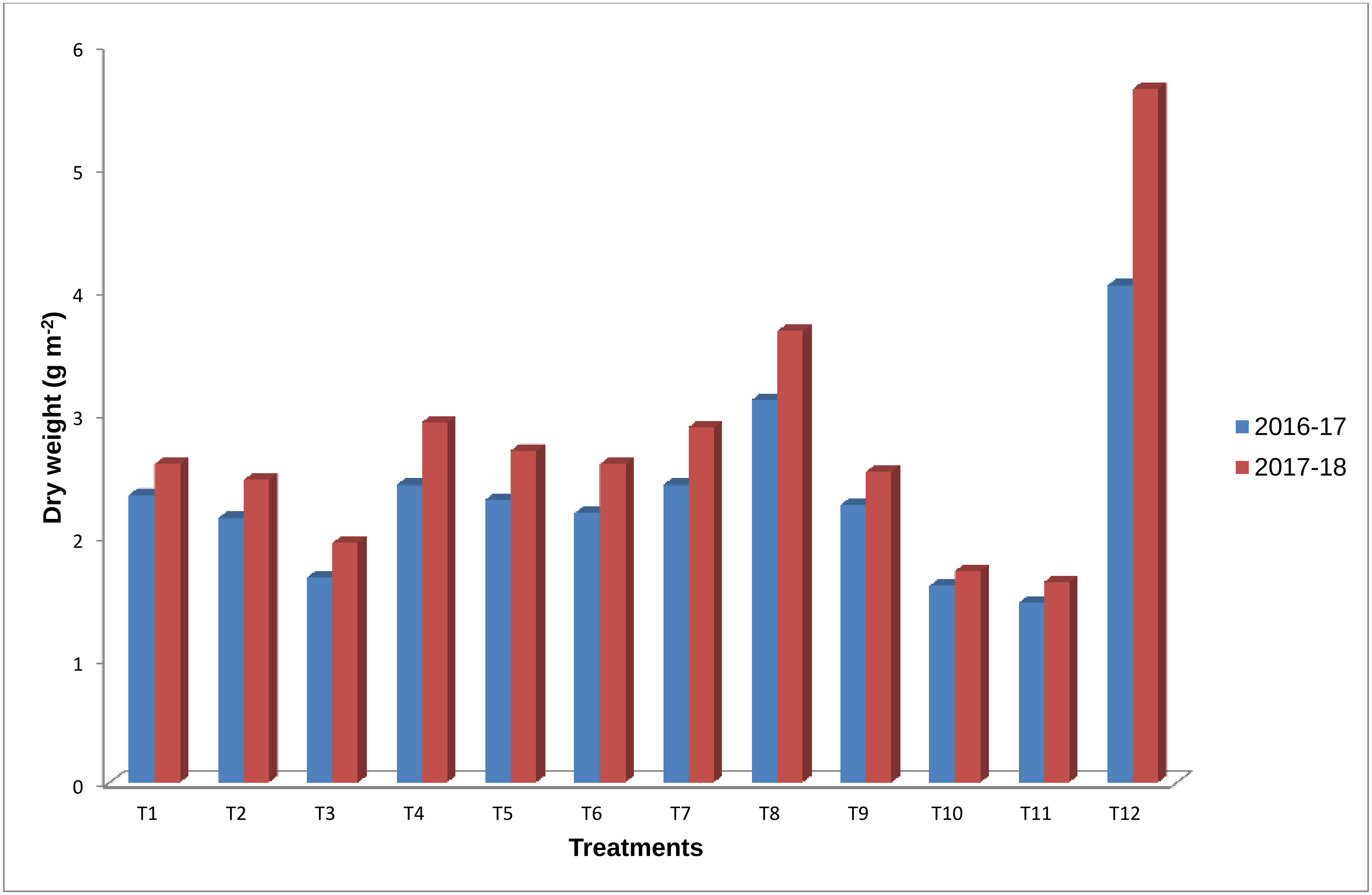

Fig. 4.12. Effect of different herbicidal treatments on dry weight of *Chenopodium album* (g m^{-2}) in wheat at 30 days after application

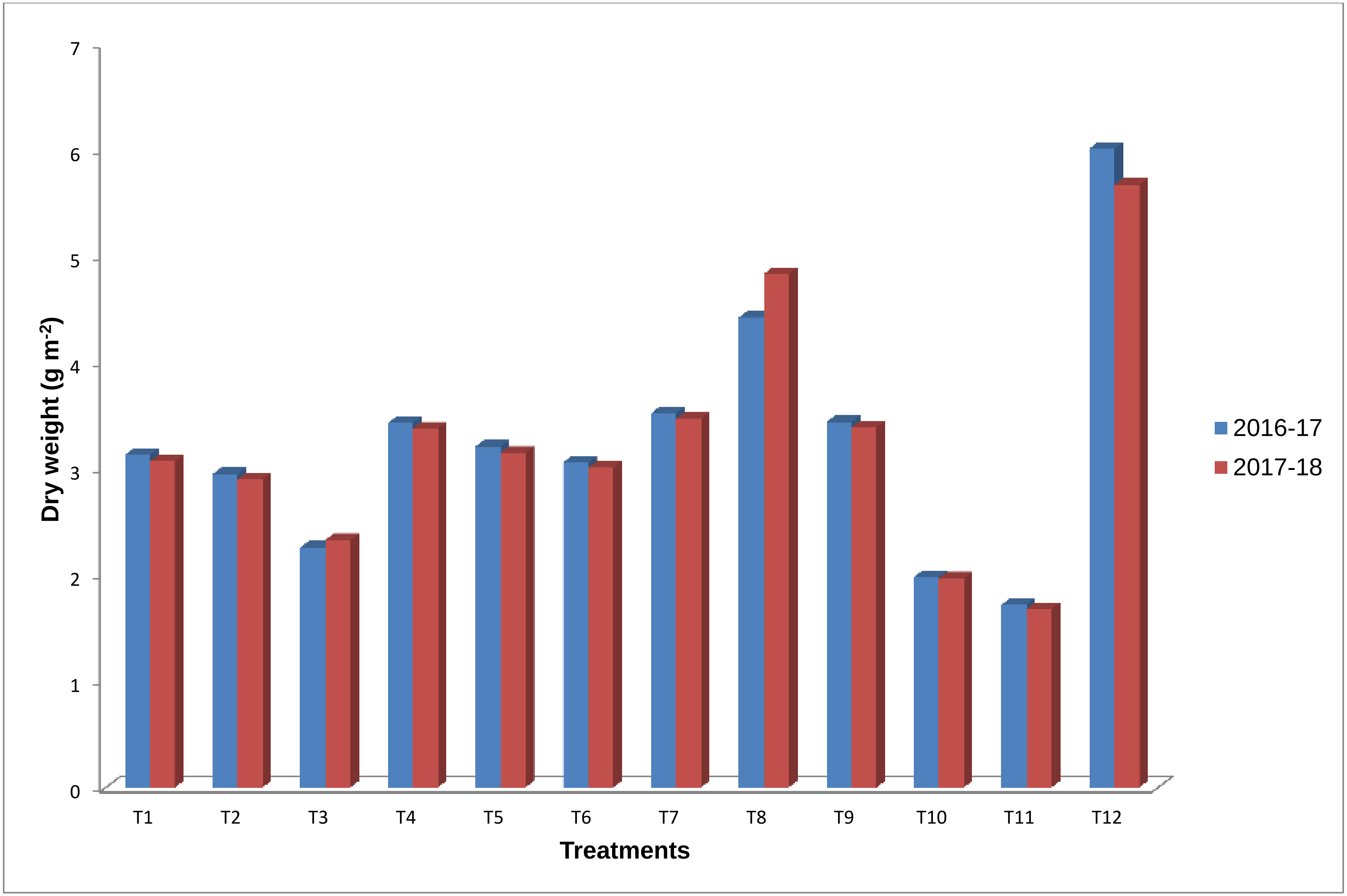

Fig. 4.13. Effect of different herbicidal treatments on dry weight of *Medicago truncatula* (gm^{-2}) in wheat at 30 days after application

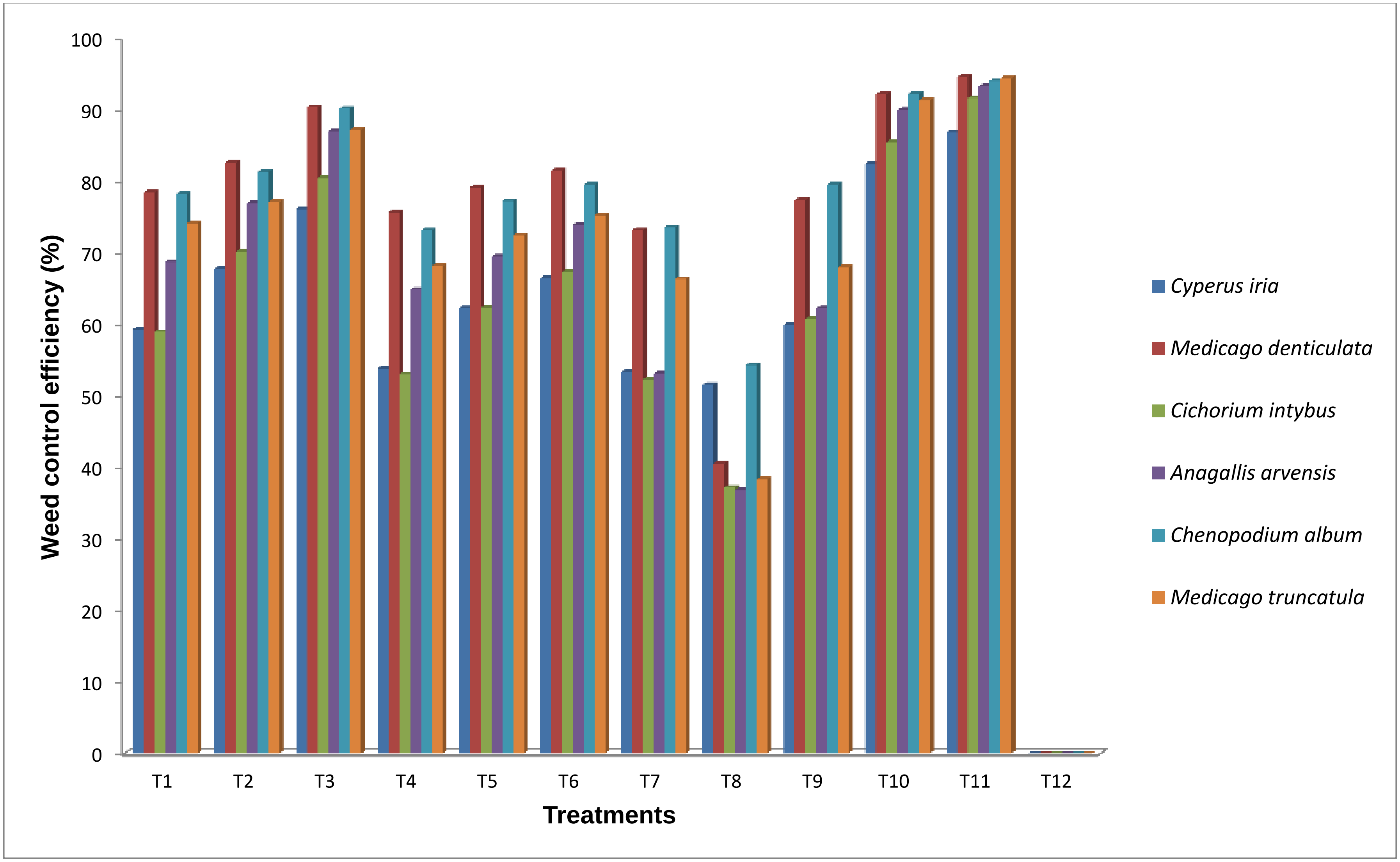

Fig. 4.14. Effect of different herbicidal treatments on weed control efficiency (%) in wheat at 30 days after application

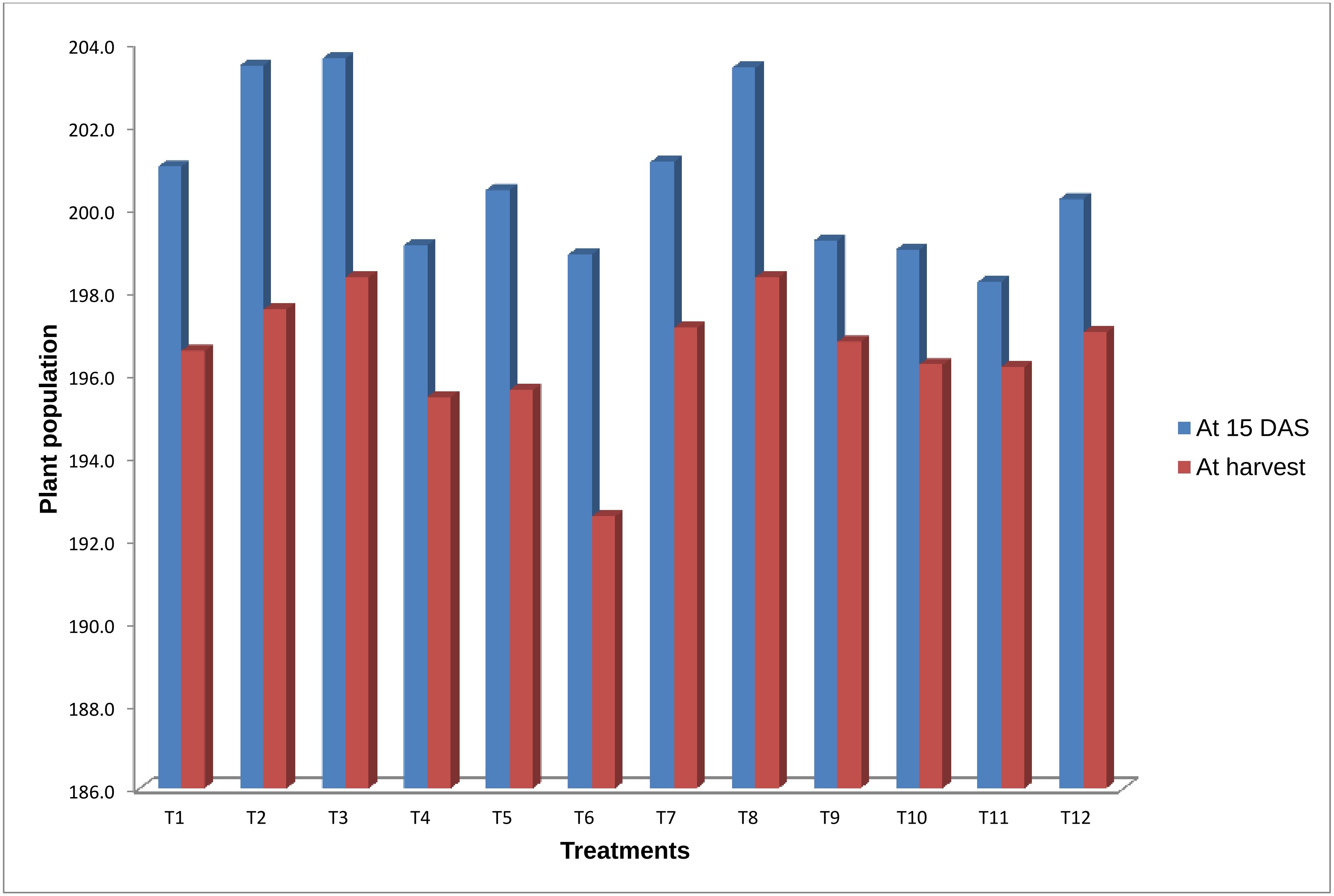

Fig. 4.15. Effect of different treatments on plant population of wheat (mean data of 2 years)

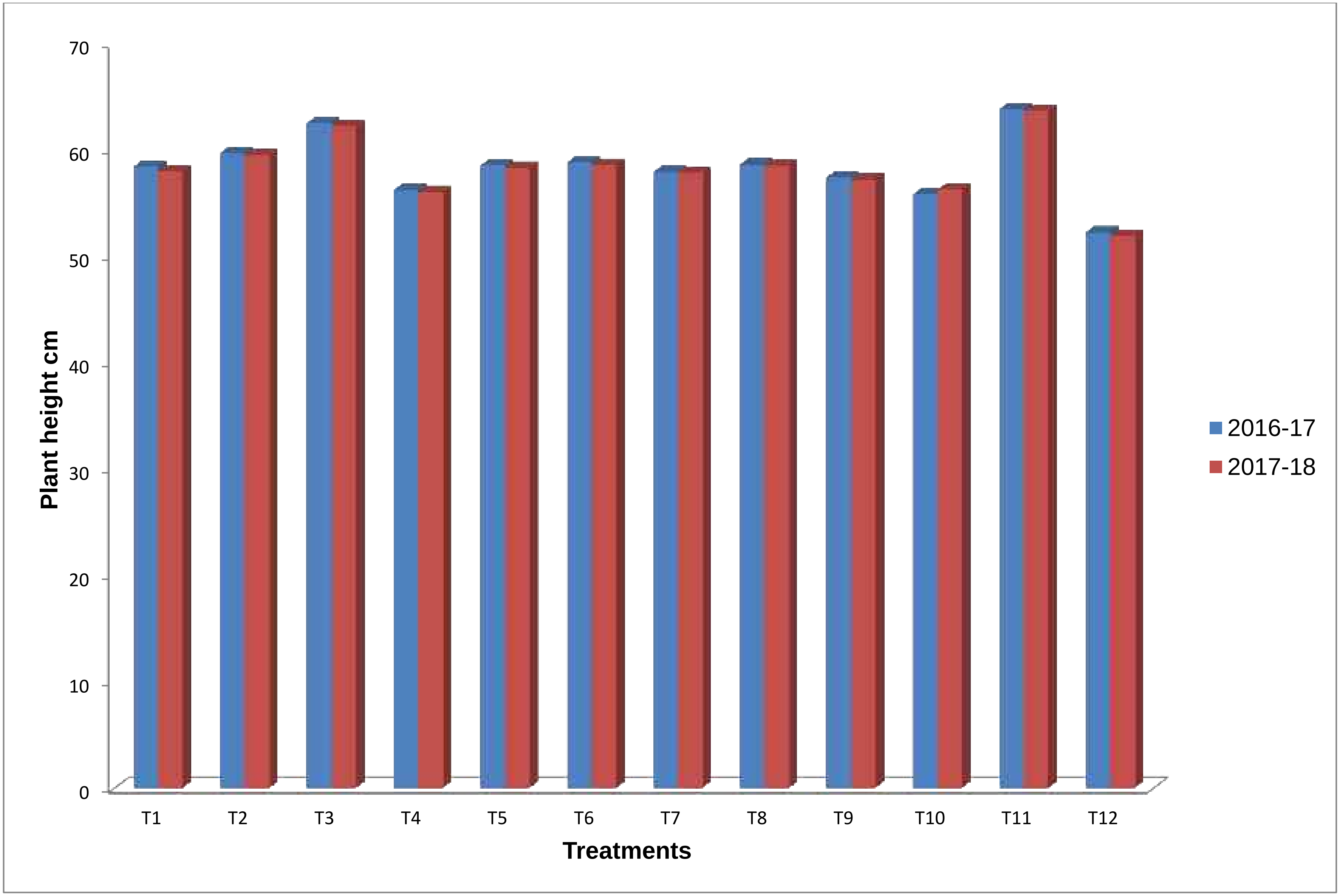

Fig. 4.16. Effect of different herbicidal treatments on plant height (cm) of wheat at 60 days after sowing

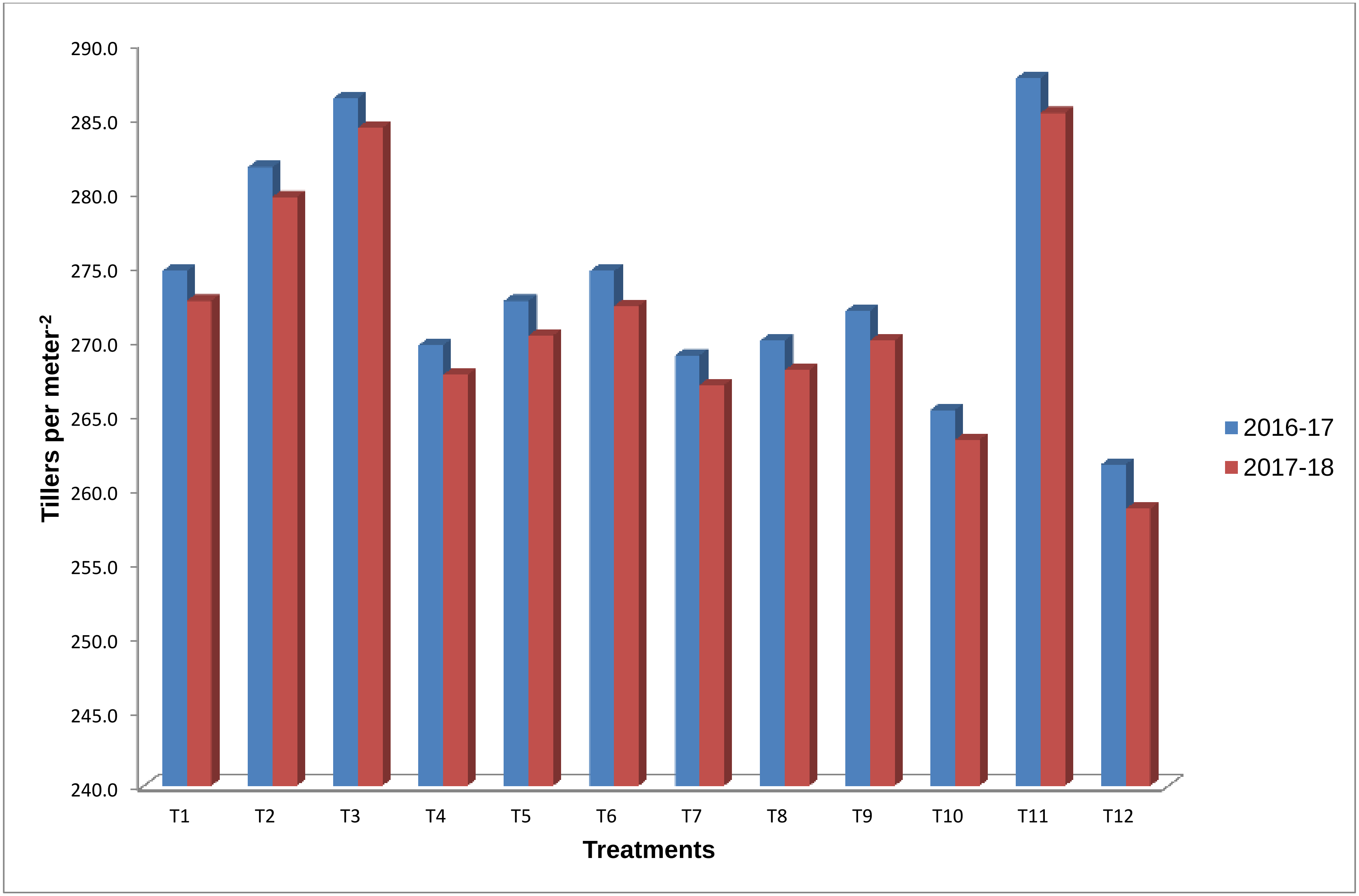

Fig. 4.17. Effect of different herbicidal treatments on tillers per meter^{-2} of wheat at 60 days after sowing

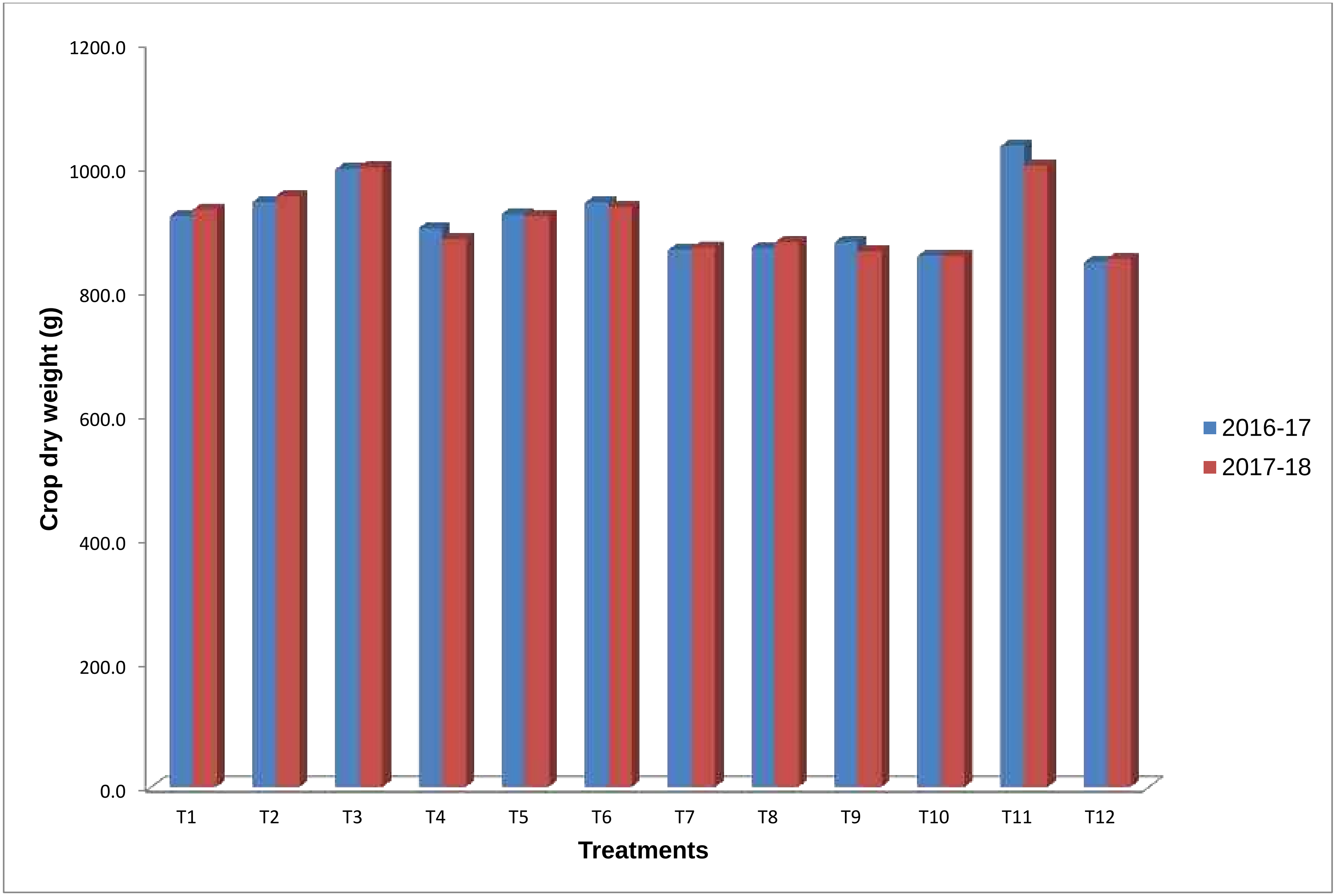

Fig. 4.18. Effect of different herbicidal treatments on crop dry weight per meter^{-2} of wheat at 60 days after sowing

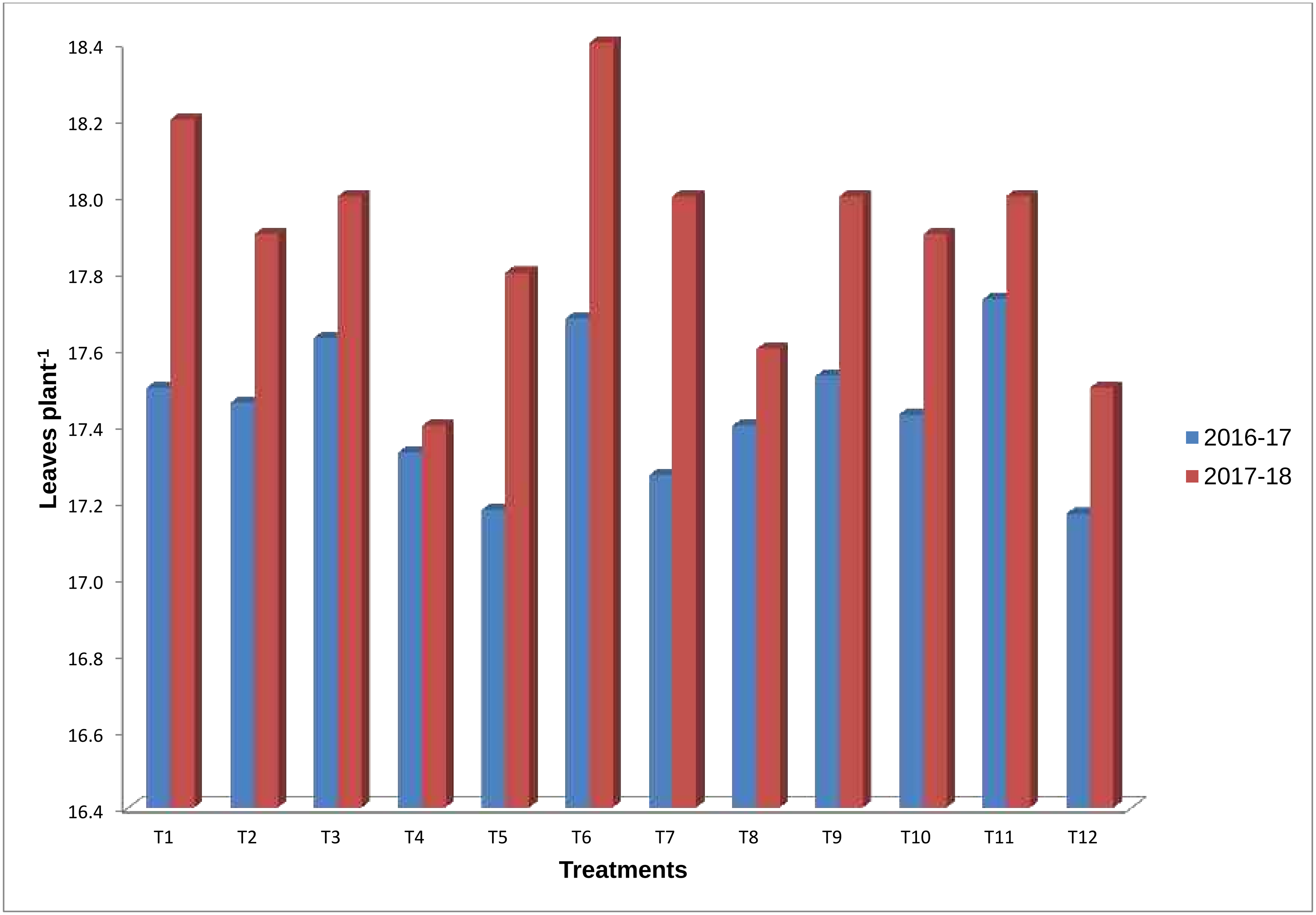

Fig. 4.19. Effect of different herbicidal treatments on leaves per plant of wheat at 60 Days after sowing

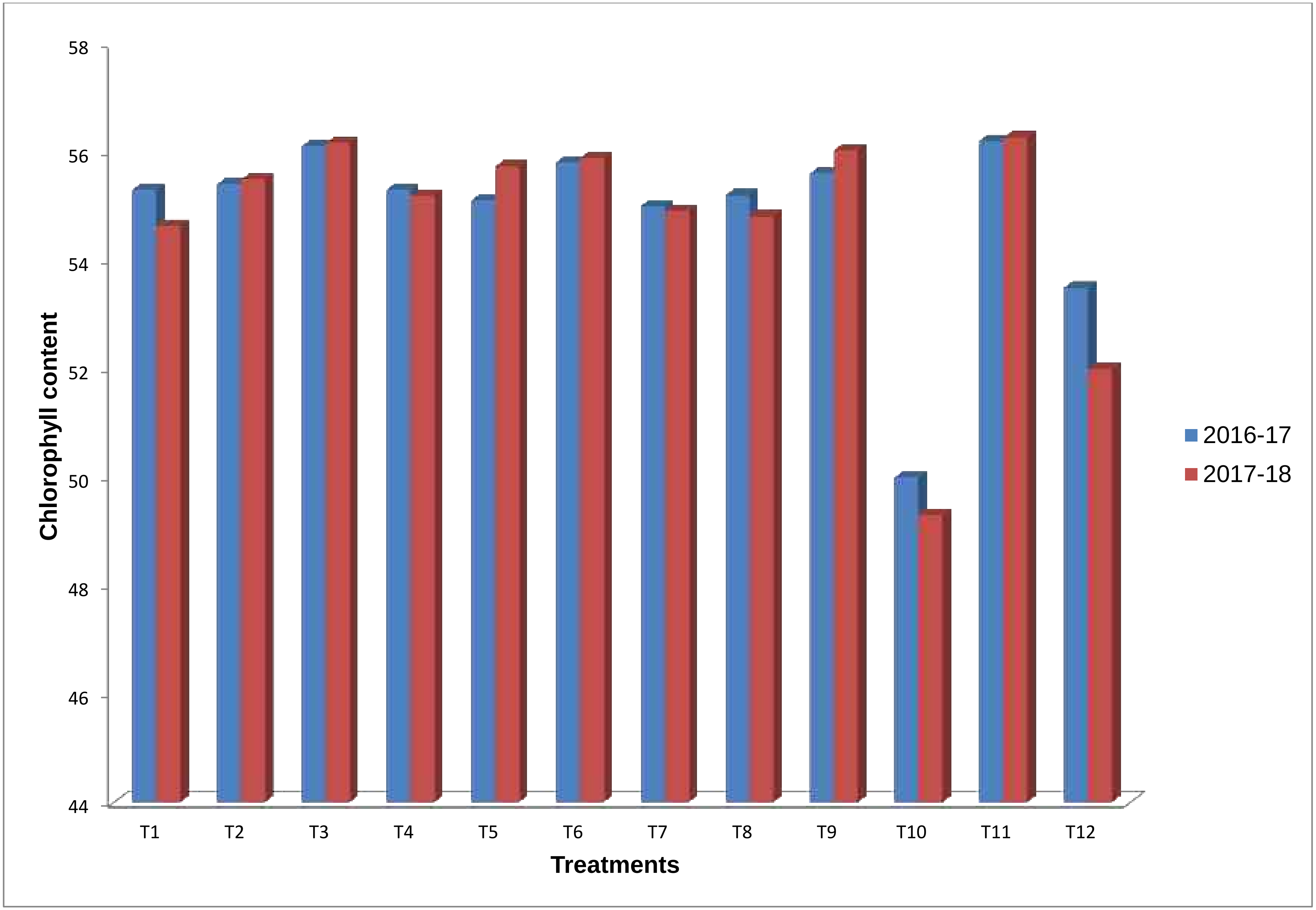

Fig. 4.20. Effect of different herbicidal treatments on chlorophyll content of wheat at 60 Days after sowing

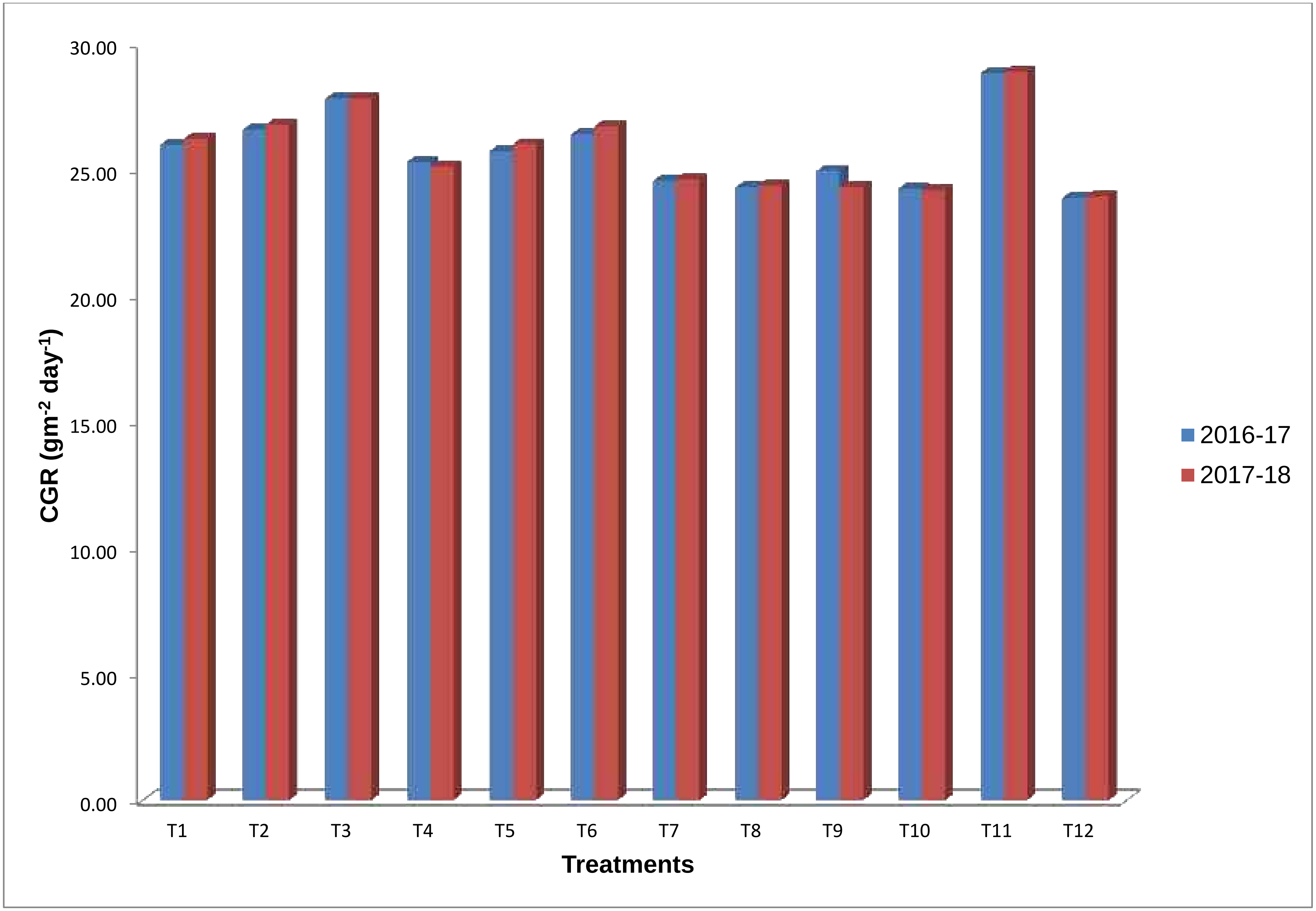

Fig. 4.21. Effect of different herbicidal treatments on CGR (gm^{-2} day^{-1}) of wheat at 30 – 60 days after sowing

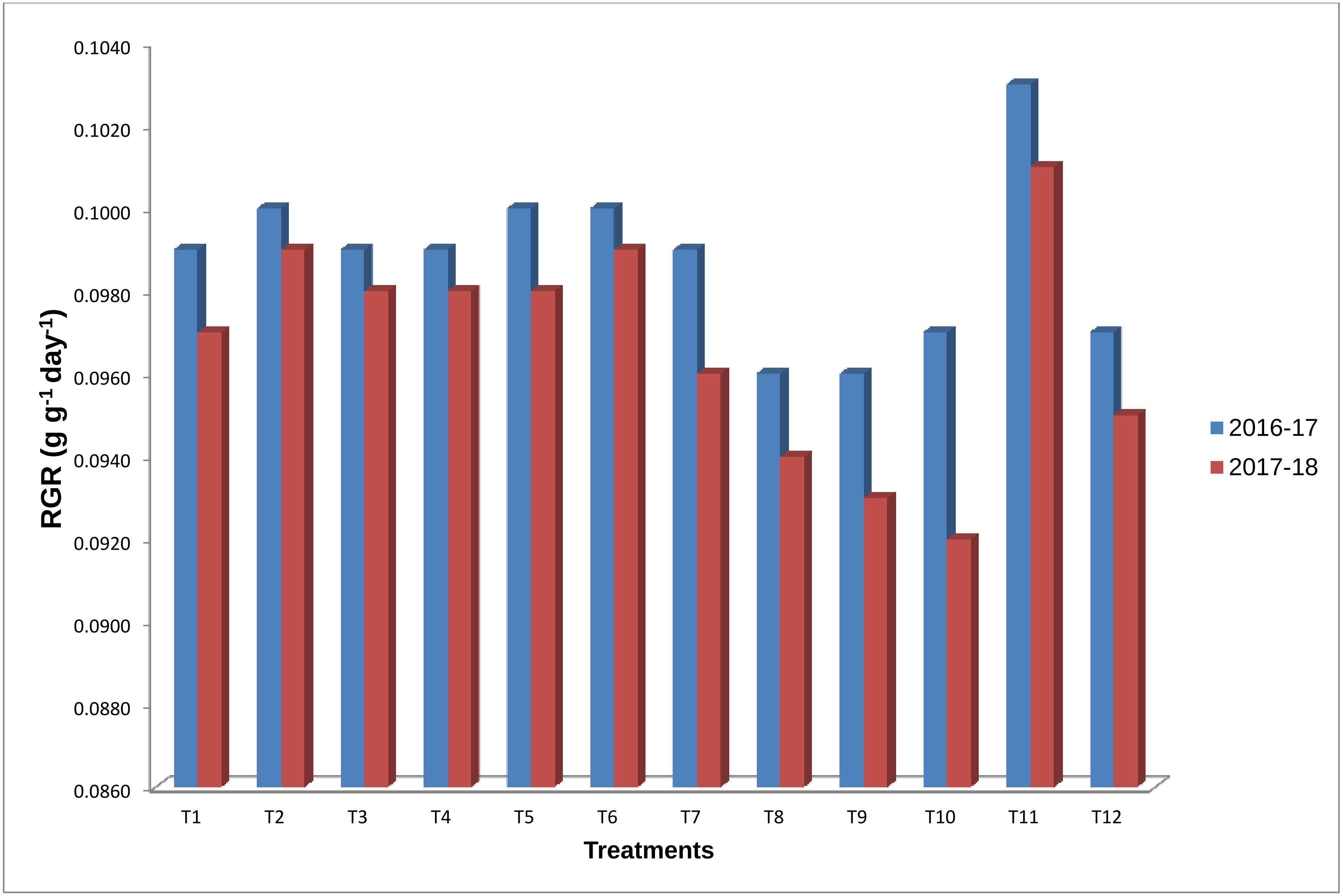

Fig. 4.22. Effect of different herbicidal treatments on RGR (g g^{-1} day^{-1}) of wheat at 30 – 60 days after sowing

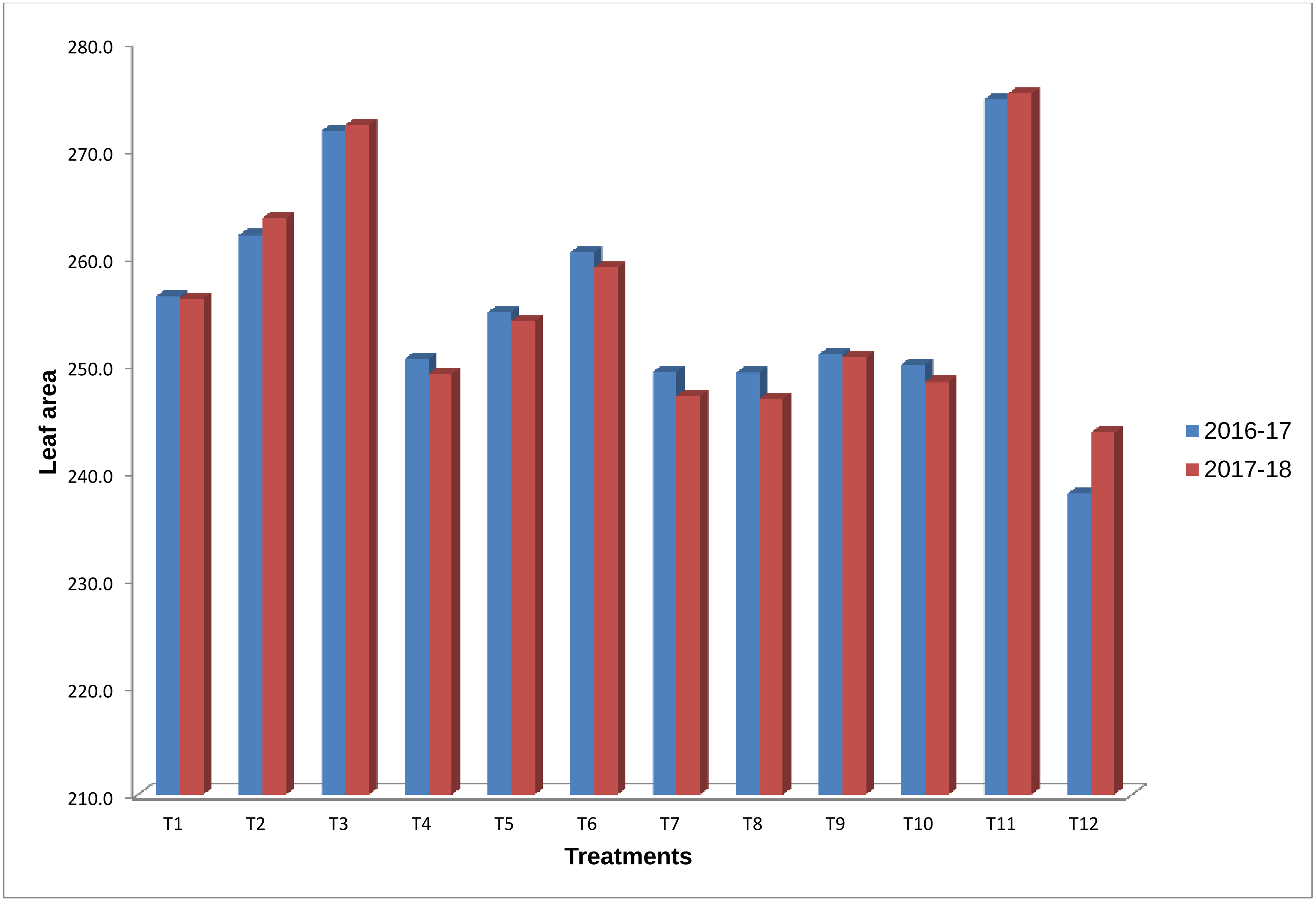

Fig. 4.23. Effect of different herbicidal treatments on leaf area of wheat at 60 days after sowing

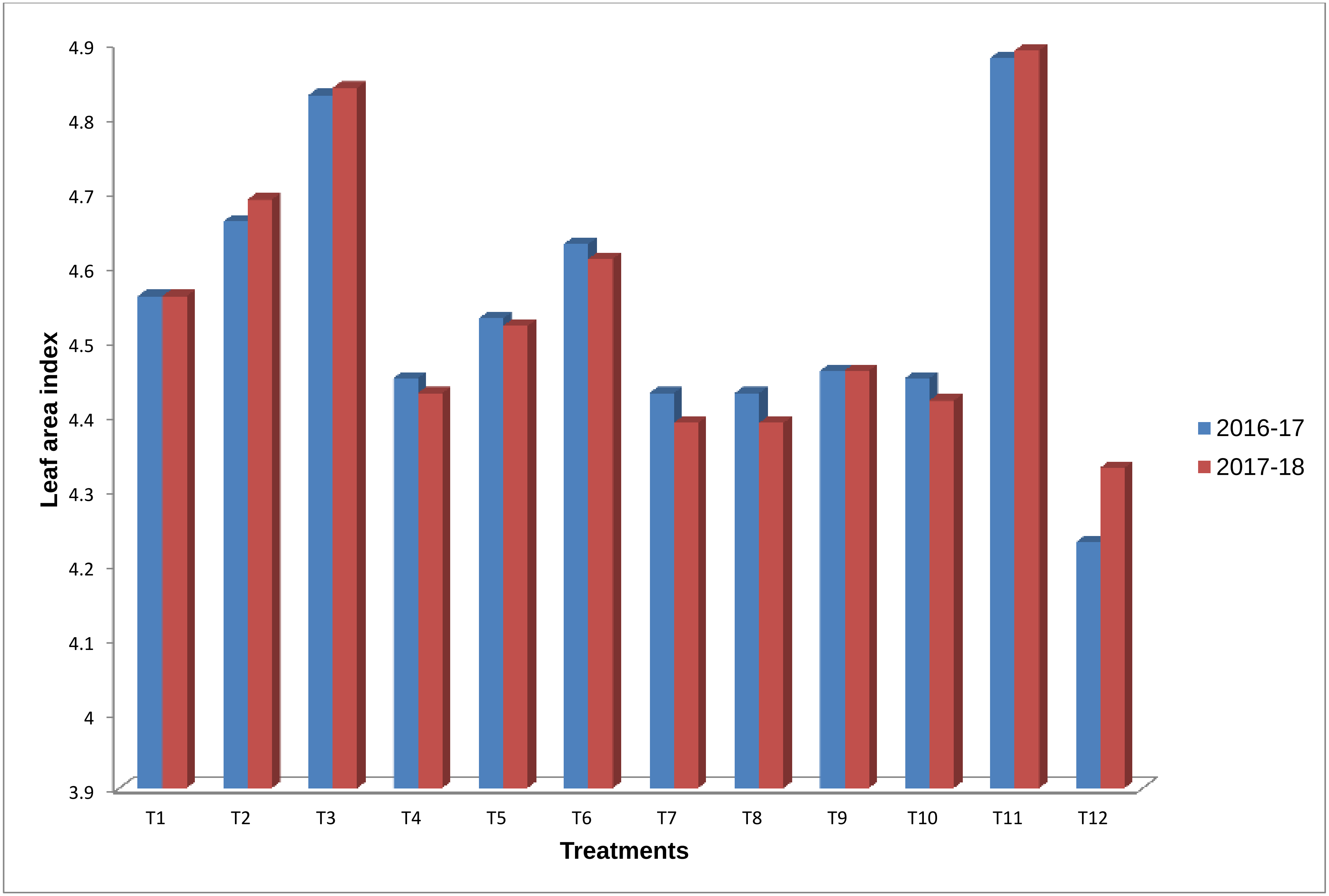

Fig. 4.24.. Effect of different herbicidal treatments on leaf area index of wheat at 60 days after sowing

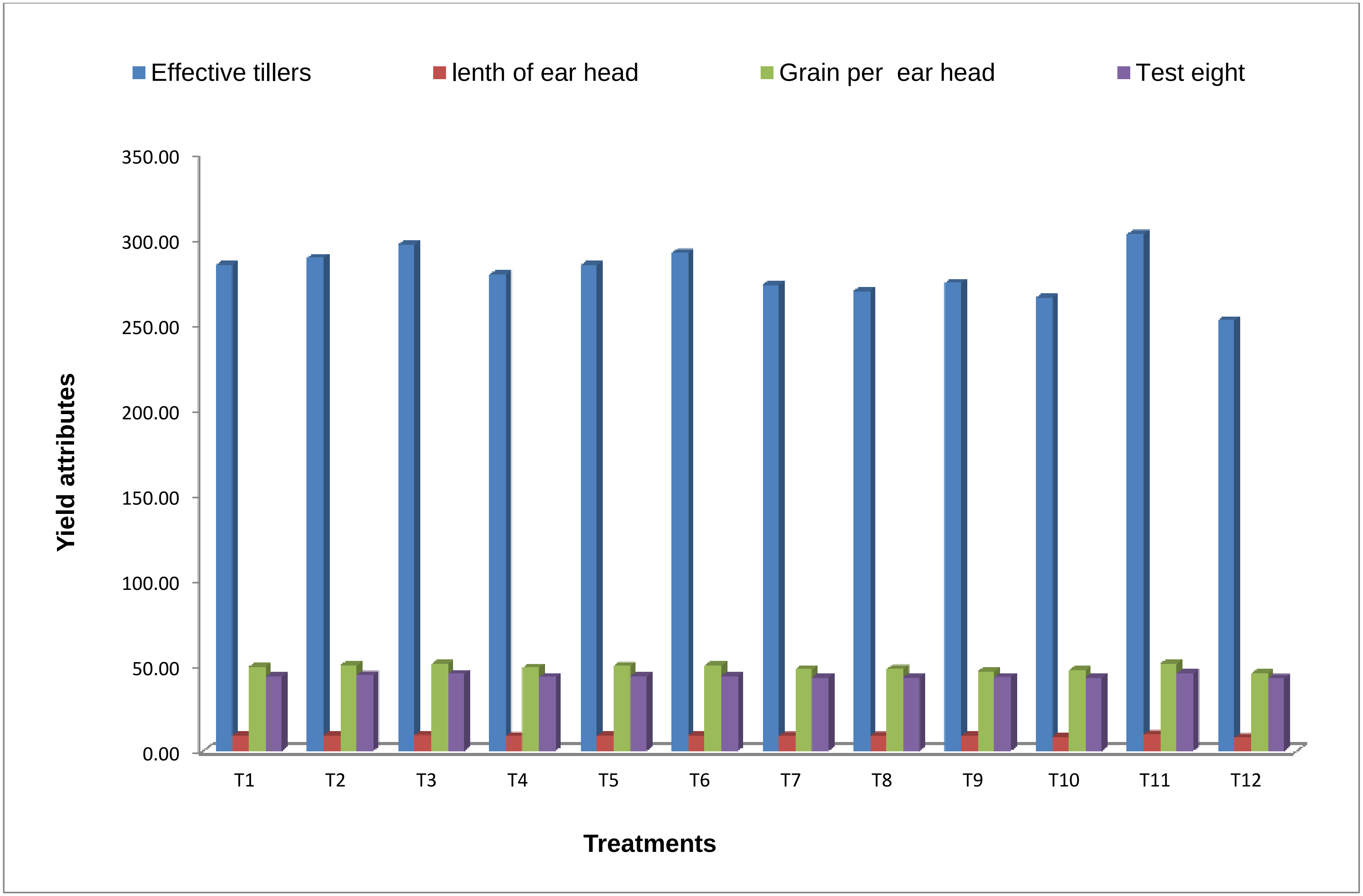

Fig. 4.25. Effect of different herbicidal treatments on yield attributes of wheat

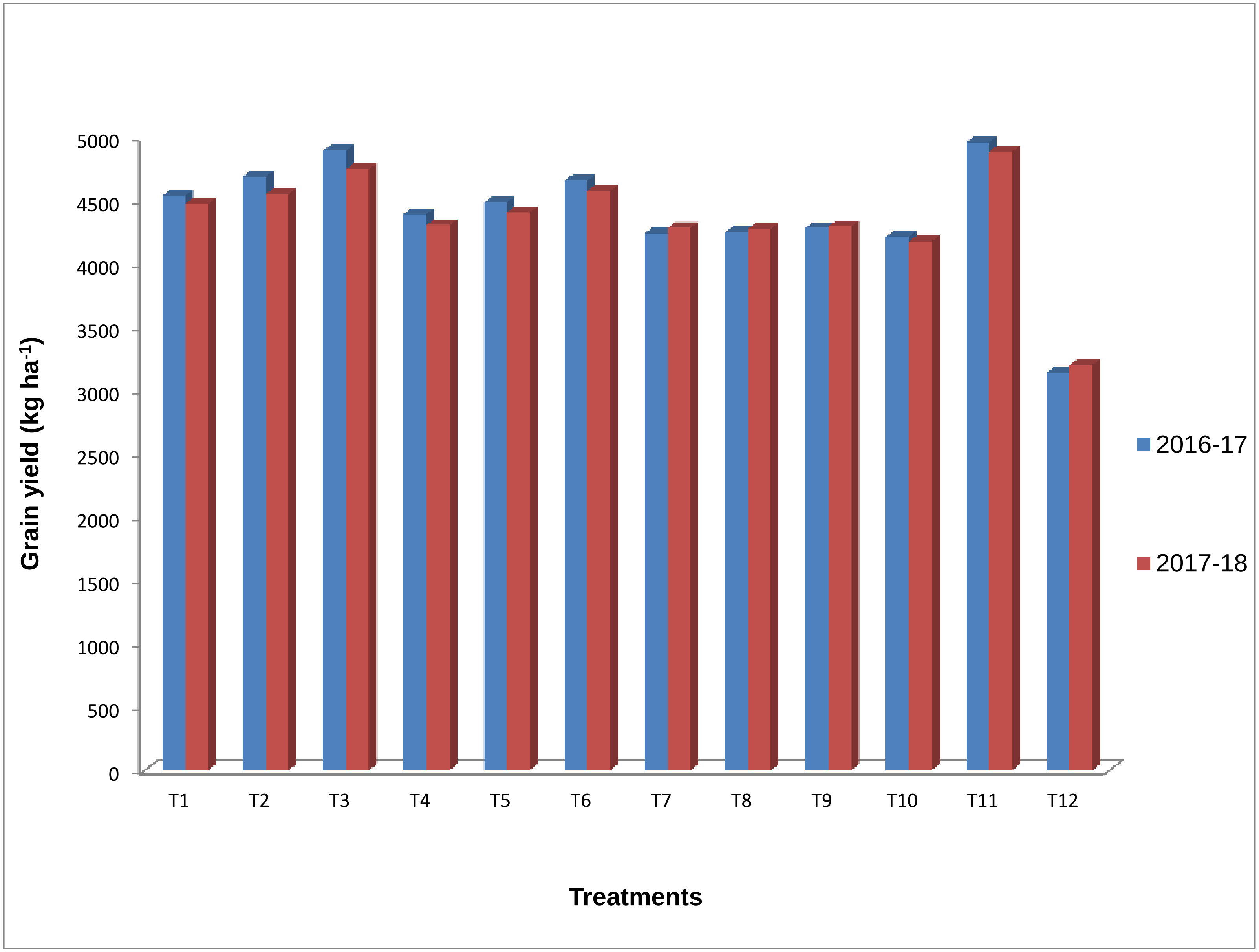

Fig. 4.26. Effect of different herbicidal treatments on grain yield (kg ha^{-1}) of wheat

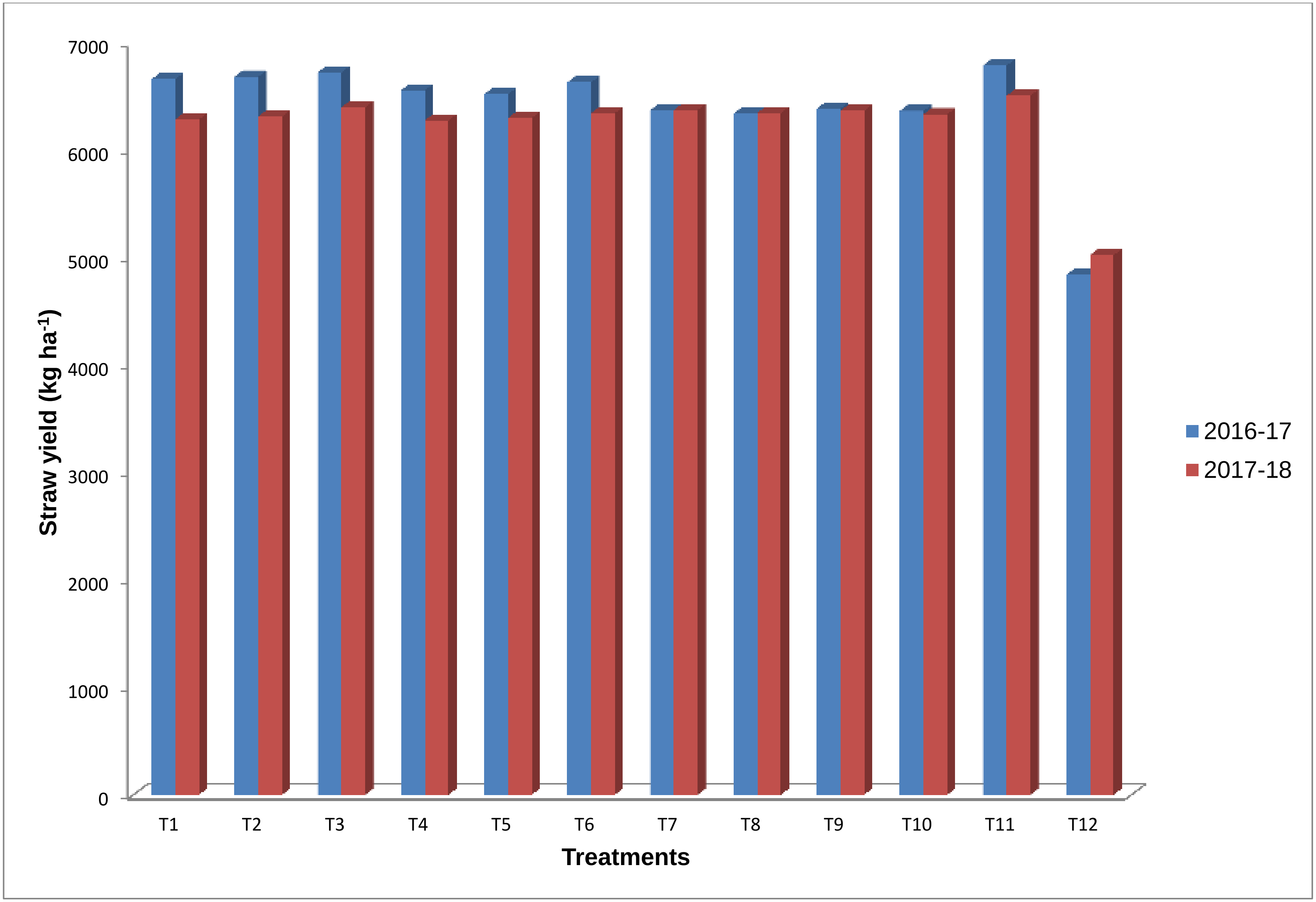

Fig. 4.27. Effect of different herbicidal treatments on straw yield (kg ha^{-1}) of wheat

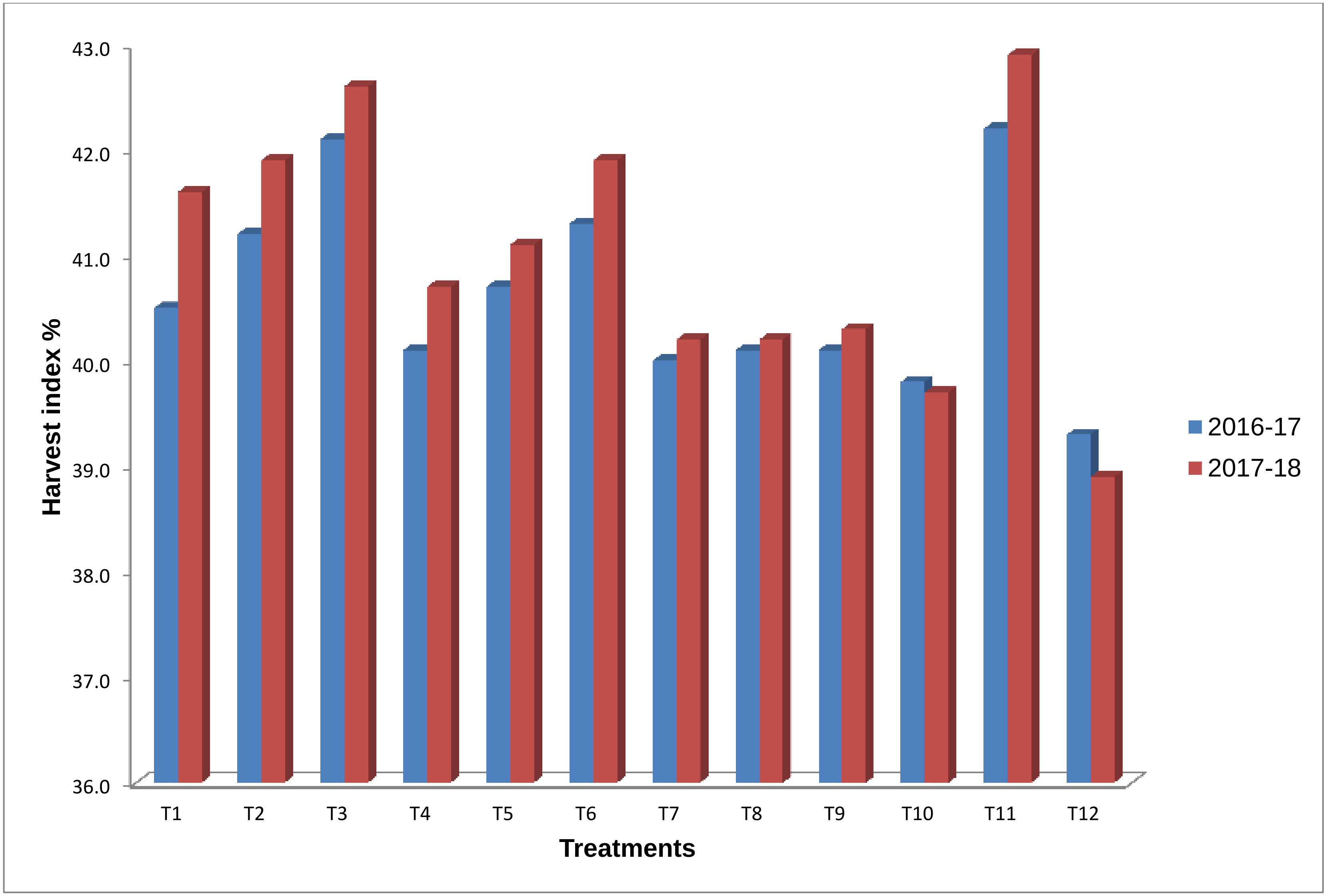

Fig. 4.28. Effect of different herbicidal treatments on harvest index (%) of wheat

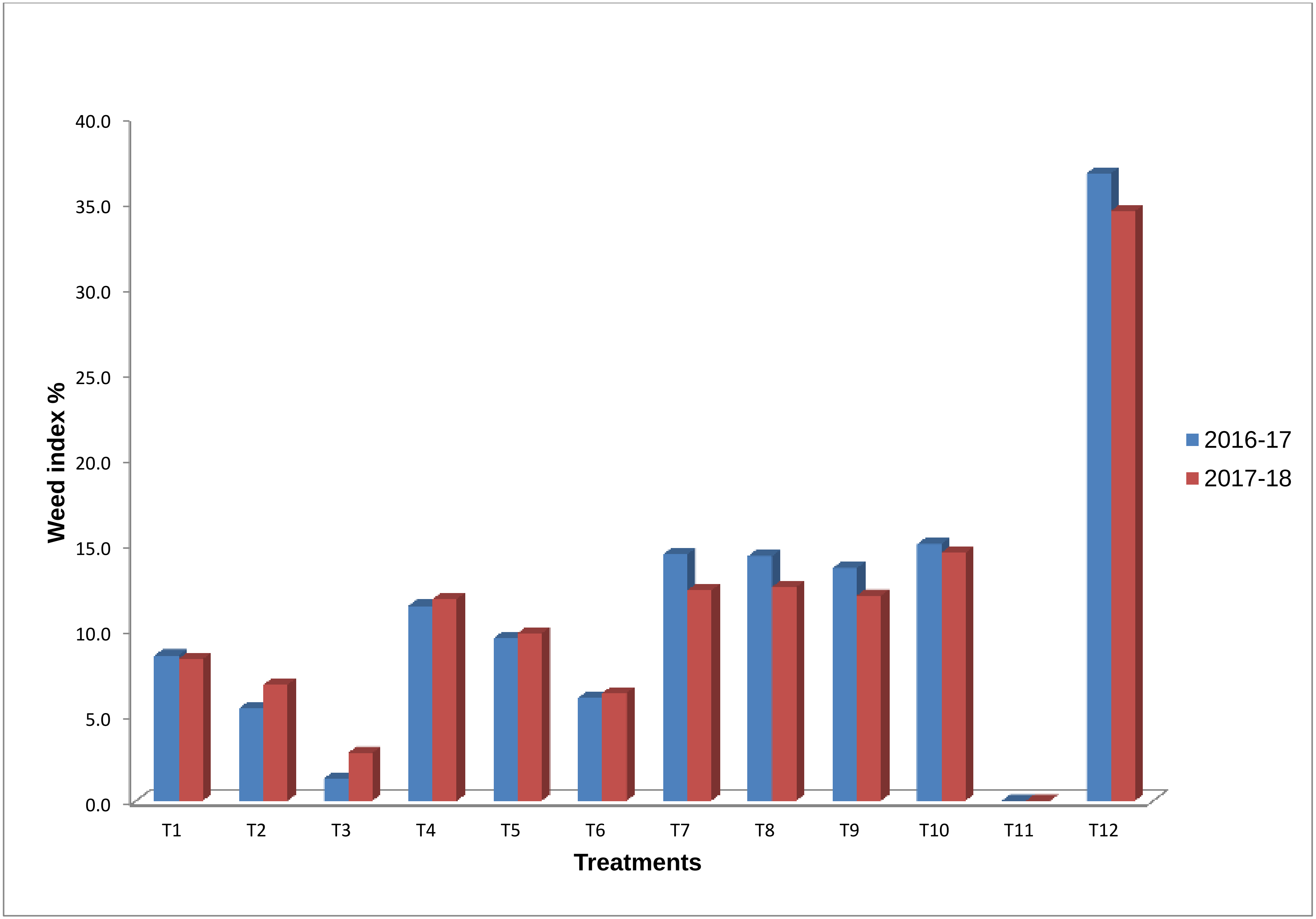

Fig. 4.29. Effect of different herbicidal treatments on weed index (%) of wheat

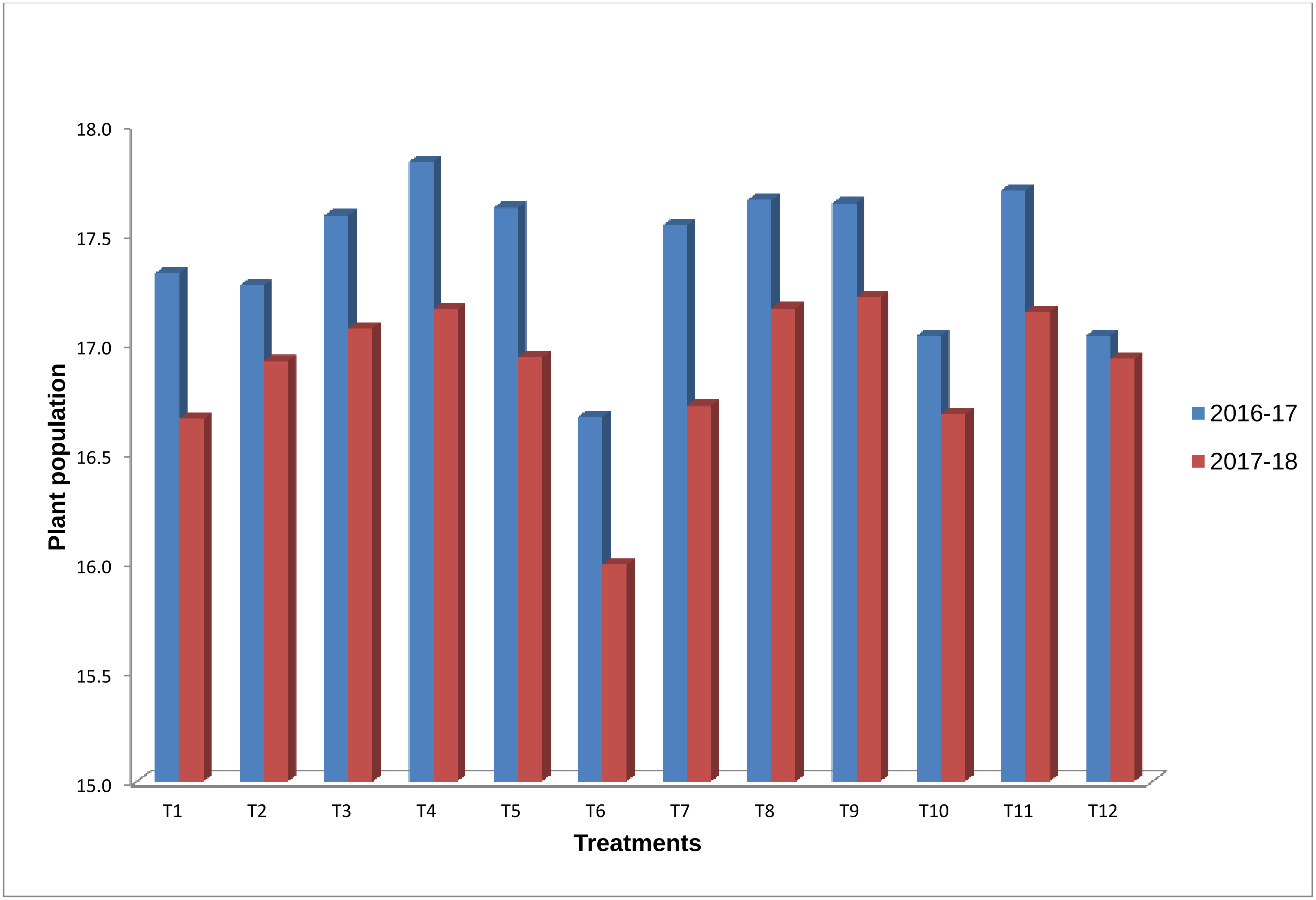

Fig. 4.30. Effect of different herbicidal treatments on plant population of succeeding soybean crop

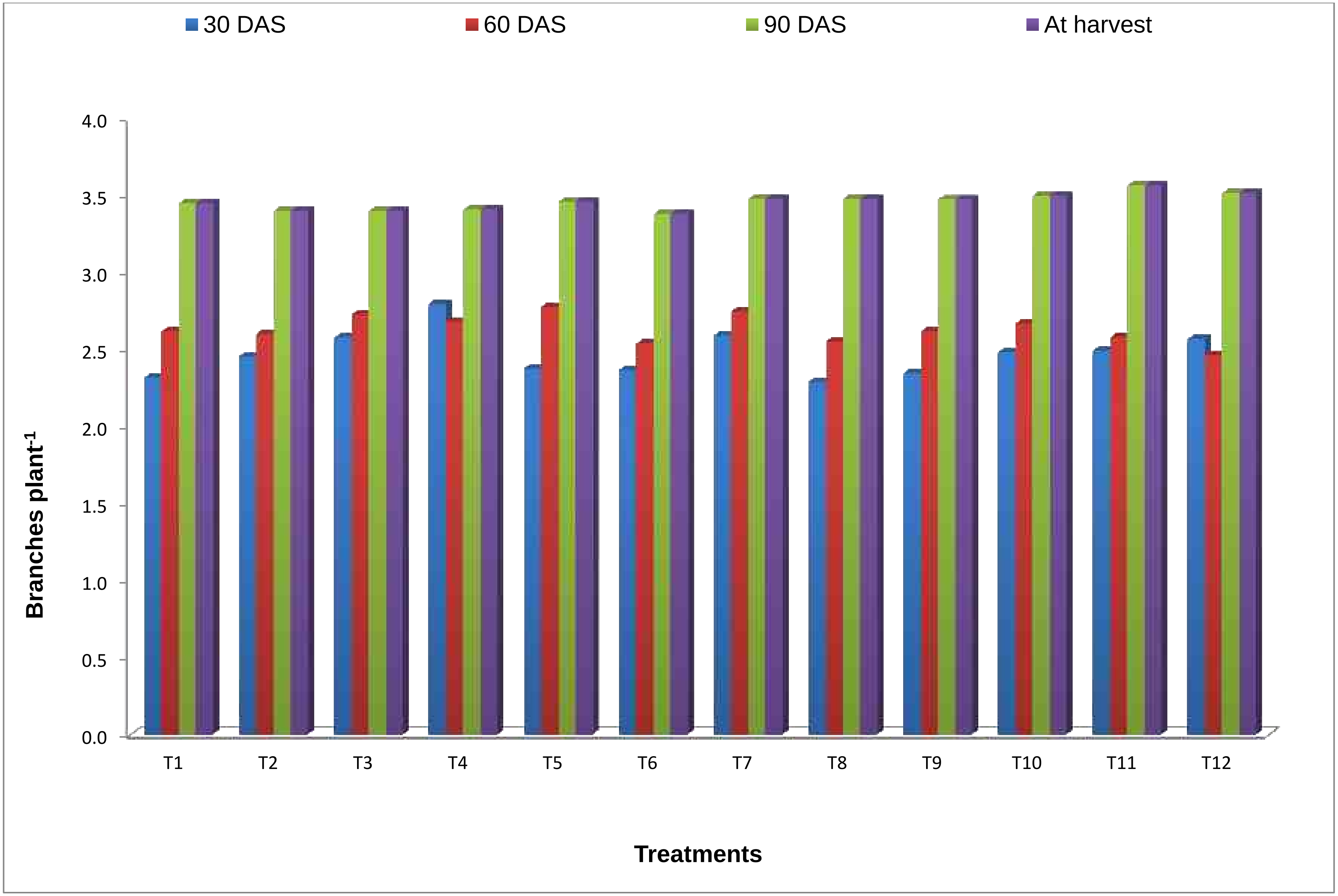

Fig 4.31. Effect of different herbicidal treatments on branches plant^{-1} of succeeding soybean crop

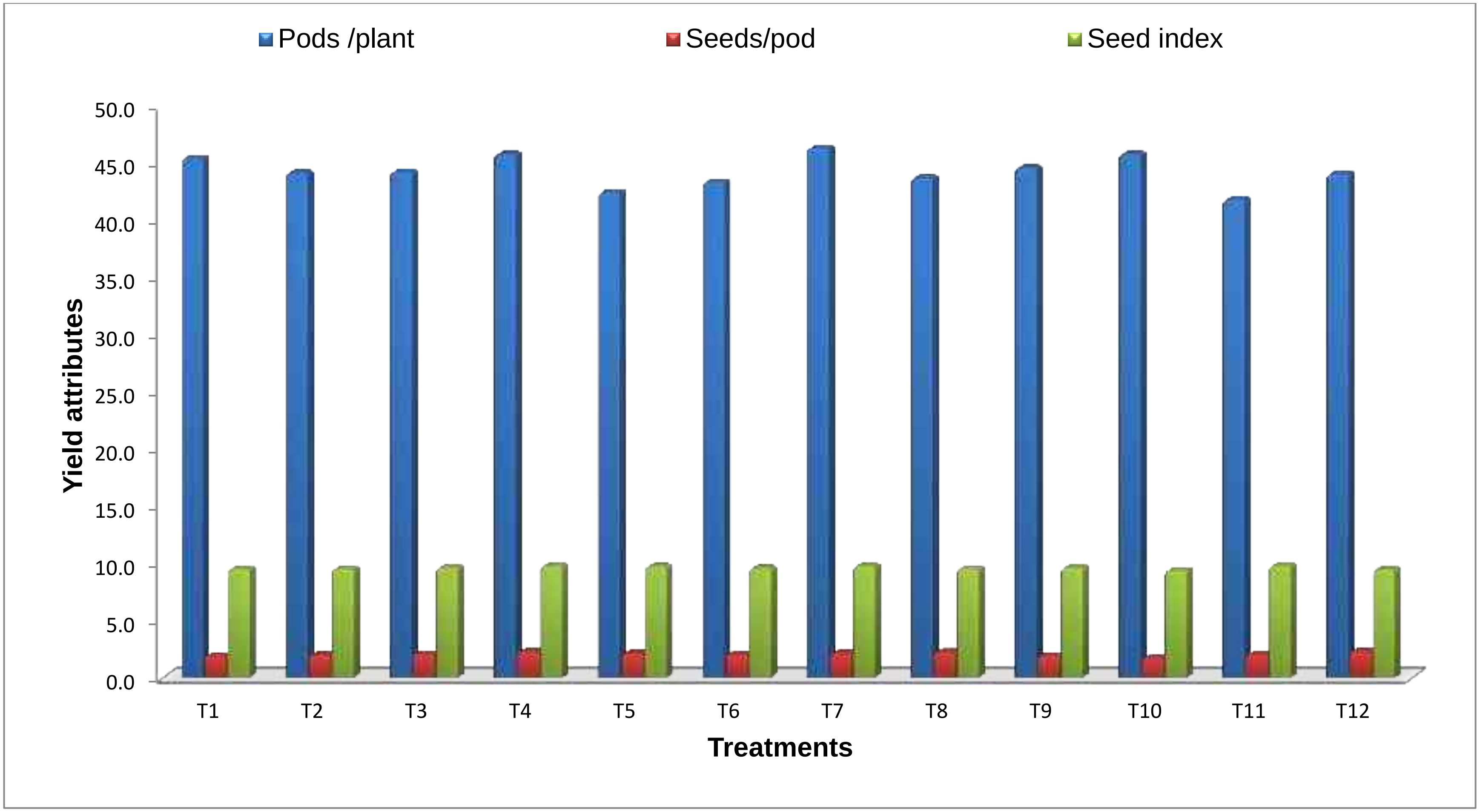

Fig. 4.32. Effect of different herbicidal treatments on yield attributes of succeeding soybean crop

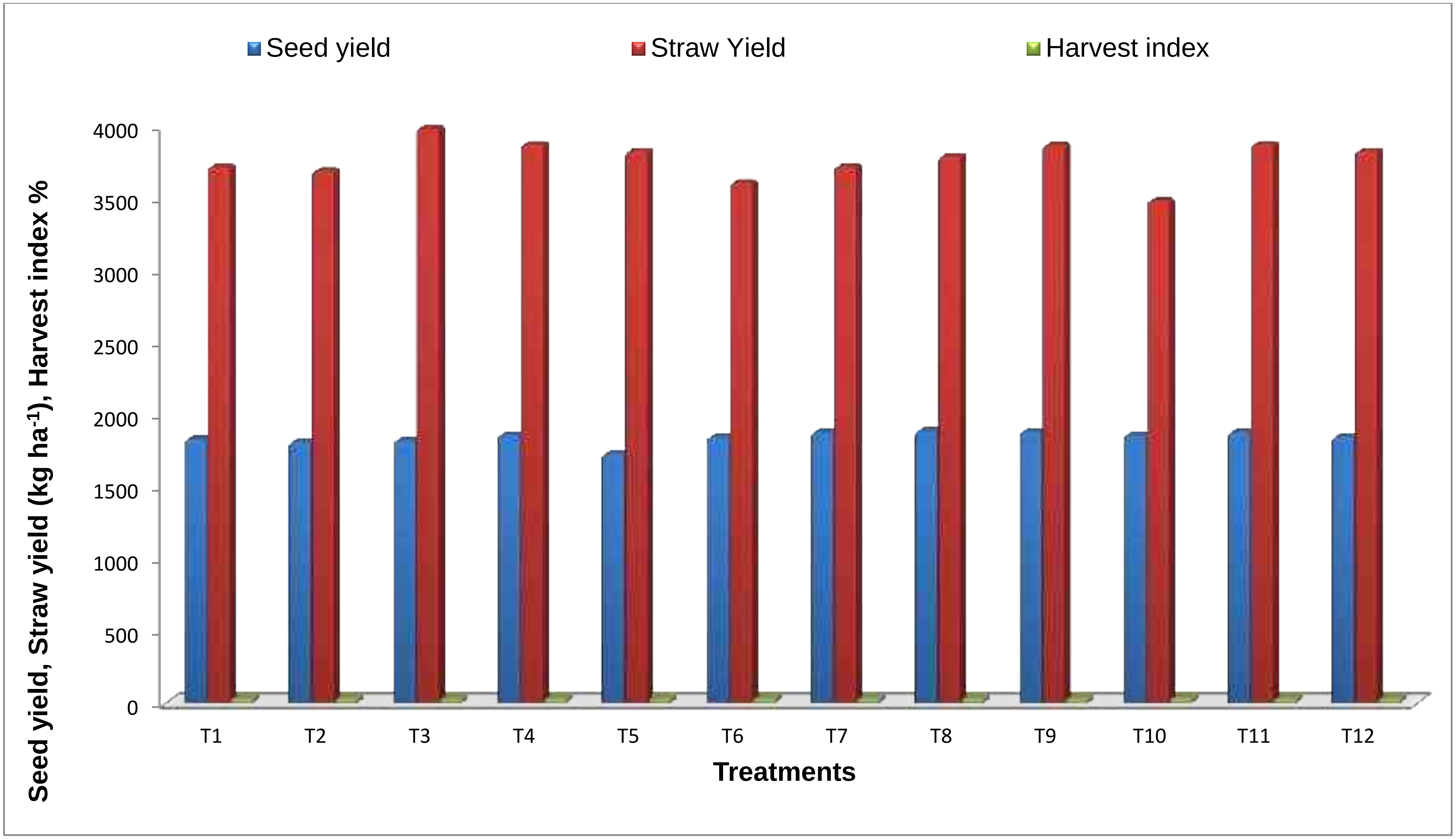

Fig. 4.33. Effect of different herbicidal treatments on seed and straw yield of succeeding soybean crop

Appendix I. Effect of different herbicidal treatments on density of *Cyperus iria* (m^{-2}) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	5.30 (27.3)	5.55 (30.0)	5.43 (28.7)	3.26 (9.7)	3.20 (9.3)	3.23 (9.5)	2.76 (6.7)	2.88 (7.3)	2.82 (7.0)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	4.71 (21.3)	5.22 (26.3)	4.97 (23.8)	3.00 (8.0)	3.11 (8.7)	3.05 (8.4)	2.37 (4.7)	2.63 (6.0)	2.50 (5.4)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	5.31 (27.3)	5.02 (24.3)	5.17 (25.8)	2.49 (5.3)	2.44 (5.0)	2.47 (5.2)	2.07 (3.3)	2.51 (5.3)	2.29 (4.3)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	4.92 (23.3)	5.38 (28.0)	5.15 (25.7)	3.46 (11.0)	3.31 (10.0)	3.38 (10.5)	2.88 (7.3)	2.99 (8.0)	2.94 (7.7)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	4.98 (24.0)	5.15 (25.7)	5.07 (24.9)	3.16 (9.0)	3.11 (8.7)	3.13 (8.9)	2.76 (6.8)	2.88 (7.3)	2.82 (7.1)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	5.25 (26.7)	5.37 (28.0)	5.31 (27.4)	2.88 (7.3)	2.99 (8.0)	2.93 (7.7)	2.63 (5.9)	2.76 (6.6)	2.70 (6.3)
T_7	Pyroxsulam 4.5% with surfactant	18.75	4.96 (24.0)	5.23 (26.7)	4.10 (25.4)	3.73 (13.0)	3.31 (10.0)	3.52 (11.5)	2.99 (8.0)	3.11 (8.7)	3.05 (8.4)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	5.06 (24.7)	5.26 (26.7)	5.16 (25.7)	3.65 (12.3)	3.50 (11.3)	3.58 (11.8)	3.08 (8.7)	3.20 (9.3)	3.14 (9.0)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	4.96 (24.0)	5.15 (25.7)	5.05 (24.9)	3.41 (10.7)	3.41 (10.7)	3.41 (10.7)	2.99 (8.0)	3.11 (8.7)	3.05 (8.4)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	5.04 (24.7)	5.24 (26.7)	5.14 (25.7)	2.37 (4.7)	2.16 (3.7)	2.26 (4.2)	1.90 (2.7)	2.07 (3.3)	1.99 (3.0)
T_{11}	Hand weeding twice	30 & 60 DAS	4.92 (23.3)	5.12 (25.3)	5.02 (24.3)	1.90 (2.7)	1.90 (32.7)	1.90 (2.7)	1.73 (2.0)	1.90 (2.7)	1.82 (2.4)
T_{12}	Control (weedy check)	-	5.19 (26.0)	5.38 (28.0)	5.29 (27.0)	5.38 (28.0)	5.19 (26.0)	5.29 (27.0)	5.51 (29.3)	4.72 (21.3)	5.12 (25.3)
SEm ±			**0.13**	**0.11**	**0.12**	**0.14**	**0.16**	**0.15**	**0.11**	**0.10**	**0.11**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.40**	**0.48**	**0.44**	**0.32**	**0.29**	**0.31**

*Figures in parenthesis are original values

Appendix II. Effect of different herbicidal treatments on density of *Medicago denticulata* (m^{-2}) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	9.76 (97.3)	9.83 (96.7)	9.80 (97.0)	3.29 (10.0)	3.68 (12.7)	3.49 (11.3)	2.99 (8.0)	3.11 (8.7)	3.05 (8.4)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	10.05 (102.3)	9.43 (88.0)	9.74 (95.2)	3.04 (8.7)	3.48 (11.3)	3.26 (10.0)	2.76 (6.7)	2.88 (7.3)	2.82 (7.0)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	7.86 (66.0)	8.44 (72.7)	8.15 (69.4)	2.87 (7.3)	2.83 (7.0)	2.85 (7.2)	2.51 (5.3)	2.63 (6.0)	2.57 (5.7)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	7.56 (58.3)	8.91 (79.3)	8.24 (68.8)	3.26 (10.0)	3.89 (14.3)	3.57 (12.2)	3.11 (8.7)	3.21 (9.3)	3.16 (9.0)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	8.08 (68.7)	9.24 (85.3)	8.66 (77.0)	3.19 (9.3)	3.69 (12.7)	3.44 (11.0)	2.88 (7.3)	3.05 (8.3)	2.97 (7.8)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	7.96 (63.7)	8.90 (79.3)	8.43 (71.5)	3.11 (8.7)	3.61 (12.0)	3.36 (10.4)	2.76 (6.7)	3.00 (8.0)	2.88 (7.4)
T_7	Pyroxsulam 4.5% with surfactant	18.75	7.33 (54.0)	7.96 (63.3)	7.65 (58.7)	3.60 (12.0)	3.91 (14.3)	3.75 (13.2)	3.31 (10.0)	3.41 (10.7)	3.36 (10.4)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	8.34 (72.3)	9.23 (84.7)	8.79 (78.5)	7.65 (57.7)	6.08 (36.0)	6.87 (46.9)	6.21 (37.7)	5.00 (24.0)	5.60 (30.9)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	7.59 (58.3)	8.35 (70.0)	7.97 (64.2)	3.30 (10.7)	3.90 (14.3)	3.60 (12.5)	3.21 (9.3)	2.99 (8.0)	3.10 (8.7)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	6.30 (45.3)	8.72 (75.3)	7.51 (60.3)	2.63 (6.0)	2.44 (5.0)	2.53 (5.5)	2.37 (4.7)	2.51 (5.3)	2.44 (5.0)
T_{11}	Hand weeding twice	30 & 60 DAS	7.64 (58.7)	8.50 (71.3)	8.07 (65.0)	1.90 (2.7)	2.07 (3.3)	1.99 (3.0)	1.79 (2.3)	1.90 (2.7)	1.85 (2.5)
T_{12}	Control (weedy check)	-	8.04 (65.7)	8.51 (72.0)	8.28 (68.9)	8.17 (66.0)	6.86 (46.0)	7.51 (56.0)	7.72 (58.7)	5.62 (30.7)	6.67 (44.7)
SEm ±			**0.93**	**0.61**	**0.77**	**0.34**	**0.20**	**0.27**	**0.16**	**0.14**	**0.15**
CD (P=0.05)			**NS**	**NS**	**NS**	**1.02**	**0.58**	**0.80**	**0.46**	**0.42**	**0.44**

*Figures in parenthesis are original values

Appendix III. Effect of different herbicidal treatments on density of *Cichorium intybus* (m^{-2}) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	5.31 (27.3)	5.62 (30.7)	5.47 (29.0)	3.78 (13.3)	3.70 (12.7)	3.74 (13.0)	3.41 (10.7)	3.41 (10.7)	3.41 (10.7)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	5.32 (27.3)	5.80 (32.7)	5.56 (30.0)	3.60 (12.0)	3.21 (9.3)	3.41 (10.7)	3.21 (9.3)	3.16 (9.0)	3.18 (9.2)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	5.06 (24.7)	5.38 (28.0)	5.22 (26.4)	2.83 (7.0)	2.99 (8.0)	2.91 (7.5)	3.04 (8.3)	3.11 (8.7)	3.08 (8.5)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	5.43 (28.7)	5.50 (29.3)	5.47 (29.0)	3.91 (14.3)	3.87 (14.0)	3.89 (14.2)	3.64 (12.3)	3.56 (11.7)	3.60 (12.0)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	5.31 (27.3)	5.38 (28.0)	5.35 (27.7)	3.77 (13.3)	3.77 (13.3)	3.77 (13.3)	3.30 (10.0)	3.36 (10.3)	3.33 (10.2)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	4.99 (24.0)	5.25 (26.7)	5.12 (25.4)	3.70 (12.7)	3.60 (12.0)	3.65 (12.4)	3.16 (9.0)	3.30 (10.0)	3.23 (9.5)
T_7	Pyroxsulam 4.5% with surfactant	18.75	5.25 (26.7)	5.44 (28.7)	5.35 (27.7)	4.18 (16.7)	4.10 (16.0)	4.14 (16.4)	4.74 (13.0)	3.60 (12.0)	3.67 (12.5)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	5.56 (30.0)	5.68 (31.3)	5.62 (30.7)	5.41 (28.3)	4.88 (23.0)	5.15 (25.7)	5.03 (24.3)	4.39 (18.3)	4.71 (21.3)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	4.99 (24.0)	5.25 (26.7)	5.12 (25.4)	3.95 (14.7)	3.87 (14.0)	3.91 (14.4)	3.54 (11.7)	3.65 (12.3)	3.60 (12.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	5.16 (26.0)	5.11 (25.3)	5.14 (25.7)	2.63 (6.0)	2.76 (6.7)	2.70 (6.4)	2.58 (5.7)	3.74 (13.0)	3.16 (9.4)
T_{11}	Hand weeding twice	30 & 60 DAS	5.10 (25.3)	5.18 (26.0)	5.14 (25.7)	2.37 (4.7)	1.79 (2.3)	2.08 (3.5)	2.31 (4.3)	1.82 (2.3)	2.07 (3.3)
T_{12}	Control (weedy check)	-	4.93 (23.3)	5.32 (27.3)	5.13 (25.3)	5.19 (26.0)	5.44 (28.7)	5.32 (27.4)	5.32 (27.3)	5.37 (28)	5.35 (27.7)
SEm ±			**0.28**	**0.23**	**0.26**	**0.19**	**0.19**	**0.19**	**0.16**	**0.15**	**0.15**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.55**	**0.56**	**0.56**	**0.48**	**0.45**	**0.47**

*Figures in parenthesis are original values

Appendix IV. Effect of different herbicidal treatments on density of *Anagallis arvensis* (m^{-2}) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	5.38 (28.0)	5.57 (30.0)	5.48 (29.0)	3.26 (10.0)	3.20 (12.0)	3.23 (11.0)	2.88 (7.3)	2.99 (8.0)	2.94 (7.7)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	5.44 (28.7)	5.67 (31.3)	5.56 (30.0)	3.00 (8.7)	3.11 (10.0)	3.05 (9.4)	2.76 (6.7)	2.88 (7.3)	2.82 (7.0)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	5.38 (28.0)	5.56 (30.0)	5.47 (29.0)	2.49 (5.3)	2.44 (6.0)	2.47 (8.3)	2.51 (5.3)	2.76 (6.7)	2.64 (6.0)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	5.06 (24.7)	5.38 (28.0)	5.22 (26.4)	3.46 (10.7)	3.31 (13.3)	3.38 (12.0)	3.11 (8.7)	3.21 (9.3)	3.16 (9.0)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	4.93 (23.3)	5.32 (27.3)	5.13 (25.3)	3.16 (10.0)	3.11 (12.0)	3.13 (11.0)	2.99 (8.0)	3.11 (8.7)	3.05 (8.4)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	4.93 (23.3)	5.19 (26.0)	5.06 (24.7)	2.88 (9.3)	2.99 (11.3)	2.93 (10.3)	2.87 (7.3)	2.99 (8.0)	2.93 (7.7)
T_7	Pyroxsulam 4.5% with surfactant	18.75	4.72 (21.3)	4.93 (23.3)	4.83 (22.3)	3.73 (12.0)	3.31 (13.3)	3.52 (12.7)	3.11 (8.7)	3.31 (10.0)	3.21 (9.4)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	5.00 (24.0)	5.38 (28.0)	5.19 (26.0)	3.65 (21.3)	3.50 (21.0)	3.58 (21.2)	4.24 (17.0)	4.43 (18.7)	4.34 (17.9)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	5.00 (24.0)	5.19 (26.0)	5.10 (25.0)	3.41 (10.7)	3.41 (14.0)	3.41 (12.4)	3.11 (8.7)	3.21 (9.3)	3.16 (9.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	5.43 (28.7)	5.55 (30.0)	5.49 (29.4)	2.37 (4.3)	2.16 (5.0)	2.26 (5.7)	2.07 (3.3)	1.90 (2.7)	1.99 (3.0)
T_{11}	Hand weeding twice	30 & 60 DAS	5.13 (25.3)	5.44 (28.7)	5.29 (27.0)	1.90 (2.7)	1.90 (3.3)	1.90 (3.0)	1.90 (2.7)	1.63 (1.7)	1.77 (2.2)
T_{12}	Control (weedy check)	-	5.06 (24.7)	4.99 (24.0)	5.03 (24.4)	5.38 (26.7)	5.19 (31.3)	5.28 (29.0)	5.31 (27.3)	5.02 (24.3)	5.17 (25.8)
SEm ±			**0.16**	**0.21**	**0.19**	**0.14**	**0.16**	**0.15**	**0.16**	**0.13**	**0.15**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.40**	**0.48**	**0.44**	**0.46**	**0.40**	**0.44**

*Figures in parenthesis are original values

Appendix V. Effect of different herbicidal treatments on density of *Chenopodium album* (m^{-2}) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	6.12 (36.7)	6.65 (43.3)	6.39 (40.0)	3.21 (9.3)	3.41 (10.7)	3.31 (10.0)	2.88 (7.3)	2.99 (8.0)	2.93 (7.7)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	5.61 (30.7)	5.94 (34.3)	5.78 (32.5)	2.99 (8.0)	3.21 (9.3)	3.10 (8.7)	2.51 (5.3)	2.63 (6.0)	2.57 (5.7)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	5.73 (32.0)	6.08 (36.0)	5.91 (34.0)	2.44 (5.0)	2.70 (6.3)	2.57 (5.7)	2.37 (4.7)	2.51 (5.3)	2.44 (5.0)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	6.00 (35.3)	6.61 (42.7)	6.31 (39.0)	3.41 (10.7)	3.65 (12.3)	3.53 (11.5)	2.99 (8.0)	3.11 (8.7)	3.05 (8.4)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	5.73 (32.0)	5.96 (34.7)	5.85 (33.4)	3.21 (9.3)	3.41 (10.7)	3.31 (10.0)	2.88 (7.3)	2.99 (8.0)	2.93 (7.7)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	5.96 (34.7)	6.18 (37.3)	6.07 (36.0)	3.11 (8.7)	3.31 (10.0)	3.21 (9.4)	2.76 (6.7)	2.88 (7.3)	2.82 (7.0)
T_7	Pyroxsulam 4.5% with surfactant	18.75	5.71 (32.0)	6.18 (37.3)	5.95 (34.7)	3.70 (12.7)	3.51 (11.3)	3.61 (12.0)	3.21 (9.3)	3.31 (10.0)	3.26 (9.7)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	5.67 (31.3)	5.91 (34.0)	5.79 (32.7)	5.07 (24.7)	5.13 (25.3)	5.10 (25.0)	4.51 (19.3)	4.32 (17.7)	4.41 (18.5)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	5.50 (29.3)	5.86 (33.3)	5.68 (31.3)	3.31 (10.0)	3.41 (10.7)	3.36 (10.4)	3.11 (8.7)	3.21 (9.3)	3.16 (9.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	5.93 (34.7)	6.28 (38.7)	6.11 (36.7)	2.29 (4.3)	2.37 (4.7)	2.33 (4.5)	2.21 (4.0)	2.34 (4.7)	2.28 (4.4)
T_{11}	Hand weeding twice	30 & 60 DAS	5.68 (31.3)	6.03 (35.3)	5.86 (33.3)	2.07 (3.3)	1.99 (3.0)	2.03 (3.2)	1.90 (2.7)	2.07 (3.3)	1.99 (3.0)
T_{12}	Control (weedy check)	-	5.68 (31.3)	6.01 (35.3)	5.85 (33.3)	5.86 (33.3)	6.02 (35.3)	5.94 (34.3)	5.79 (32.7)	5.57 (30.0)	5.68 (31.4)
SEm ±			**0.33**	**0.23**	**0.28**	**0.14**	**0.13**	**0.14**	**0.16**	**0.15**	**0.16**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.41**	**0.37**	**0.39**	**0.48**	**0.44**	**0.46**

*Figures in parenthesis are original value

Appendix VI. Effect of different herbicidal treatments on density of *Medicago truncatula* (m^2) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	7.32 (52.7)	7.46 (54.7)	7.39 (53.7)	3.78 (13.3)	3.68 (12.7)	3.73 (13.0)	3.31 (10.0)	3.11 (8.7)	3.21 (9.4)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	6.99 (48.0)	7.14 (50.0)	7.07 (49.0)	3.31 (10.0)	3.20 (9.3)	3.26 (9.7)	3.11 (8.7)	2.88 (7.3)	3.00 (8.0)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	7.19 (50.7)	7.32 (52.7)	7.26 (51.7)	2.89 (7.3)	2.99 (7.83	2.86 (8.4)	2.76 (6.7)	2.51 (5.3)	2.63 (6.0)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	7.72 (58.7)	7.85 (60.7)	7.79 (59.7)	4.03 (15.3)	3.95 (14.7)	3.99 (15.0)	3.67 (12.7)	3.49 (11.3)	3.58 (12.0)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	7.41 (54.0)	7.54 (56.0)	7.48 (55.0)	3.87 (14.0)	3.77 (13.3)	3.82 (13.7)	3.41 (10.7)	3.20 (9.3)	3.31 (10.0)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	7.35 (53.3)	7.53 (56.0)	7.44 (54.7)	3.60 (12.0)	3.51 (11.3)	3.55 (11.7)	3.20 (9.3)	2.99 (8.0)	3.09 (8.7)
T_7	Pyroxsulam 4.5% with surfactant	18.75	7.26 (52.0)	7.45 (54.7)	7.36 (53.4)	4.03 (15.3)	3.95 (14.7)	3.99 (15.0)	3.78 (13.3)	3.60 (12.0)	3.69 (12.7)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	7.09 (49.3)	7.14 (50.0)	7.12 (49.7)	5.64 (31.0)	5.13 (25.3)	5.38 (28.2)	4.96 (23.7)	4.35 (18.0)	4.66 (20.9)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	7.45 (54.7)	7.49 (55.3)	7.47 (55.0)	4.04 (15.3)	3.96 (14.7)	4.00 (15.0)	3.49 (11.3)	3.31 (10.0)	3.40 (10.7)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	7.27 (52.0)	7.32 (52.7)	7.30 (52.4)	2.52 (5.3)	2.44 (5.0)	2.48 (6.4)	2.37 (4.7)	2.07 (3.3)	2.22 (4.0)
T_{11}	Hand weeding twice	30 & 60 DAS	7.41 (54.0)	7.50 (55.3)	7.46 (54.7)	2.07 (3.3)	1.90 (2.7)	1.98 (3.0)	1.90 (2.7)	1.63 (1.7)	1.76 (2.2)
T_{12}	Control (weedy check)	-	7.31 (52.7)	7.44 (54.7)	7.38 (53.7)	7.41 (54.0)	6.68 (43.7)	7.05 (48.9)	7.41 (54.7)	6.07 (36.0)	6.74 (45.4)
SEm ±			**0.27**	**0.25**	**0.26**	**0.17**	**0.16**	**0.17**	**0.26**	**0.17**	**0.21**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.50**	**0.47**	**0.49**	**0.76**	**0.51**	**0.63**

*Figures in parenthesis are original values

Appendix VII. Effect of different herbicidal treatments on dry weight of *Cyperus iria* (g m^2) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	2.48 (5.2)	2.59 (5.7)	2.53 (5.5)	2.24 (4.0)	2.21 (3.9)	2.22 (4.00)	2.05 (3.2)	2.11 (3.5)	2.08 (3.4)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	2.25 (4.1)	2.46 (5.1)	2.36 (4.6)	2.08 (3.3)	2.14 (3.3)	2.11 (3.3)	1.72 (2.0)	1.87 (2.5)	1.80 (2.3)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	2.49 (5.2)	2.37 (4.6)	2.43 (4.9)	1.79 (2.2)	1.75 (2.8)	1.77 (2.5)	1.55 (1.4)	1.80 (2.3)	1.68 (1.9)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	2.33 (4.4)	2.53 (5.4)	2.43 (4.9)	2.36 (3.6)	2.27 (4.1)	2.31 (4.4)	2.02 (3.1)	2.08 (3.4)	2.05 (3.3)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	2.35 (4.5)	2.43 (4.9)	2.39 (4.7)	2.18 (3.7)	2.15 (3.6)	2.16 (3.7)	1.97 (2.8)	2.02 (3.1)	2.00 (3.0)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	2.50 (5.4)	2.55 (5.7)	2.53 (5.6)	2.01 (3.1)	2.07 (3.3)	2.04 (3.2)	1.86 (2.5)	1.95 (2.8)	1.90 (2.7)
T_7	Pyroxsulam 4.5% with surfactant	18.75	2.37 (4.8)	2.49 (5.3)	2.43 (5.1)	2.53 (5.4)	2.27 (4.2)	2.40 (4.8)	2.08 (3.4)	2.15 (3.7)	2.12 (3.6)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	2.41 (4.9)	2.49 (5.3)	2.45 (5.1)	2.48 (5.1)	2.38 (4.7)	2.43 (4.9)	2.15 (3.7)	2.22 (4.0)	2.19 (3.9)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	2.34 (4.5)	2.43 (4.9)	2.38 (4.7)	2.33 (4.5)	2.33 (4.5)	2.33 (4.5)	2.09 (3.4)	2.16 (3.7)	2.12 (3.6)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	2.43 (5.1)	2.51 (5.5)	2.47 (5.3)	1.71 (1.9)	1.59 (2.2)	1.65 (2.1)	1.45 (1.1)	1.55 (1.4)	1.50 (1.3)
T_{11}	Hand weeding twice	30 & 60 DAS	2.36 (4.7)	2.44 (5.0)	2.40 (4.9)	1.44 (1.1)	1.45 (1.4)	1.44 (1.3)	1.37 (0.8)	1.46 (1.1)	1.41 (1.0)
T_{12}	Control (weedy check)	-	2.47 (5.2)	2.55 (5.6)	2.51 (5.4)	3.56 (11.7)	3.44 (10.9)	3.50 (11.3)	3.66 (12.4)	3.16 (9.0)	3.41 (10.7)
SEm ±			**0.13**	**0.11**	**0.12**	**0.08**	**0.10**	**0.09**	**0.11**	**0.10**	**0.11**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.24**	**0.29**	**0.27**	**0.32**	**0.29**	**0.31**

*Figures in parenthesis are original values

Appendix VIII. Effect of different herbicidal treatments on dry weight of *Medicago denticulata* ($g\ m^2$) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	2.67 (6.3)	2.69 (6.3)	2.68 (6.30)	2.68 (6.3)	3.42 (10.8)	3.05 (8.6)	2.81 (8.0)	3.00 (8.1)	2.91 (8.1)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	2.80 (7.0)	2.64 (6.0)	2.72 (6.50)	2.44 (5.2)	3.03 (8.4)	2.74 (6.8)	2.60 (6.7)	2.73 (6.5)	2.67 (6.6)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	2.23 (4.3)	2.37 (4.7)	2.30 (4.50)	2.31 (4.4)	2.86 (5.0)	2.58 (4.7)	2.33 (5.3)	2.48 (5.2)	2.41 (5.3)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	2.22 (4.0)	2.54 (5.5)	2.38 (4.75)	2.67 (6.4)	3.56 (12.8)	3.12 (9.6)	2.93 (8.8)	3.14 (8.9)	3.04 (8.8)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	2.34 (4.7)	2.61 (5.9)	2.48 (5.30)	2.58 (5.8)	3.29 (11.0)	2.98 (8.4)	2.72 (7.3)	2.85 (7.2)	2.79 (7.3)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	2.26 (4.2)	2.49 (5.2)	2.38 (4.70)	2.49 (5.2)	3.23 (10.0)	2.86 (7.6)	2.58 (6.7)	2.73 (6.5)	2.66 (6.6)
T_7	Pyroxsulam 4.5% with surfactant	18.75	2.16 (3.7)	2.31 (4.4)	2.24 (4.05)	2.96 (7.8)	3.74 (13.0)	3.35 (10.4)	3.14 (10.0)	3.35 (10.2)	3.25 (10.1)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	2.43 (5.1)	2.64 (6.0)	2.54 (5.55)	6.20 (37.5)	5.87 (33.5)	6.03 (35.5)	5.83 (33.1)	4.93 (23.3)	5.38 (28.2)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	2.24 (4.1)	2.42 (4.9)	2.33 (4.50)	2.75 (7.0)	3.40 (10.6)	3.07 (8.8)	2.99 (9.3)	2.83 (7.1)	2.91 (8.2)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	1.99 (3.3)	2.53 (5.4)	2.26 (4.35)	2.09 (3.4)	2.44 (3.4)	2.27 (3.4)	2.16 (4.7)	2.38 (4.7)	2.27 (4.7)
T_{11}	Hand weeding twice	30 & 60 DAS	2.22 (4.0)	2.42 (4.9)	2.32 (4.45)	1.53 (1.4)	1.80 (2.3)	1.66 (1.9)	1.64 (2.3)	1.77 (2.2)	1.71 (2.3)
T_{12}	Control (weedy check)	-	2.28 (4.3)	2.37 (4.7)	2.33 (4.50)	6.04 (35.6)	6.48 (40.9)	6.26 (38.3)	7.29 (58.7)	5.48 (29.1)	6.39 (43.9)
SEm ±			**0.22**	**0.14**	**0.18**	**0.26**	**0.18**	**0.22**	**0.14**	**0.14**	**0.14**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.78**	**0.54**	**0.66**	**0.42**	**0.41**	**0.42**

*Figures in parenthesis are original values

Appendix IX. Effect of different herbicidal treatments on dry weight of *Cichorium intybus* (g m^2) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	1.72 (1.90)	1.86 (2.5)	1.79 (2.2)	2.84 (7.1)	2.78 (6.7)	2.81 (6.9)	3.12 (8.7)	2.85 (7.1)	2.98 (7.9)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	1.70 (1.90)	1.90 (2.6)	1.80 (2.3)	2.63 (5.9)	2.36 (4.6)	2.50 (5.3)	2.92 (7.6)	2.57 (6.0)	2.74 (6.8)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	1.65 (1.)	1.88 (2.5)	1.77 (2.1)	2.07 (3.3)	2.18 (3.8)	2.13 (3.55)	2.83 (7.1)	2.49 (5.2)	2.66 (6.2)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	1.72 (2.00)	1.91 (2.6)	1.82 (2.3)	2.95 (7.7)	2.92 (7.6)	2.94 (7.7)	3.33 (10.1)	3.03 (8.2)	3.18 (9.2)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	1.72 (1.86)	1.87 (2.5)	1.80 (2.2)	2.78 (6.8)	2.78 (6.8)	2.78 (6.8)	3.07 (8.5)	2.83 (7.0)	2.95 (7.8)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	1.63 (1.67)	1.84 (2.4)	1.74 (2.1)	2.66 (6.1)	2.60 (5.8)	2.63 (6.0)	2.92 (7.6)	2.74 (6.6)	2.83 (7.1)
T_7	Pyroxsulam 4.5% with surfactant	18.75	1.70 (1.87)	1.90 (2.6)	1.80 (2.3)	3.22 (9.5)	3.16 (9.1)	3.19 (9.3)	3.43 (10.8)	3.12 (8.8)	3.28 (9.8)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	1.75 (2.10)	1.87 (2.5)	1.81 (2.3)	4.18 (16.4)	3.78 (13.3)	3.98 (14.9)	4.63 (20.4)	3.81 (13.6)	4.22 (17.0)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	1.64 (1.65)	1.84 (2.4)	1.74 (2.1)	2.95 (7.8)	2.90 (7.4)	2.93 (7.6)	3.26 (9.7)	2.98 (7.9)	3.12 (8.8)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	1.65 (1.75)	1.81 (2.3)	1.73 (2.1)	1.90 (2.6)	1.97 (2.9)	1.93 (2.8)	2.37 (4.6)	2.90 (7.4)	2.63 (6.0)
T_{11}	Hand weeding twice	30 & 60 DAS	1.67 (1.76)	1.83 (2.3)	1.75 (2.1)	1.88 (2.6)	1.39 (1.0)	1.64 (1.8)	2.14 (3.6)	1.54 (1.4)	1.84 (2.5)
T_{12}	Control (weedy check)	-	1.62 (1.6)	1.78 (2.2)	1.70 (1.9)	4.29 (17.4)	5.09 (24.9)	4.69 (21.2)	4.69 (21.0)	5.10 (25.2)	4.90 (23.1)
SEm ±			**0.06**	**0.06**	**0.06**	**0.13**	**0.14**	**0.14**	**0.15**	**0.13**	**0.14**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.39**	**0.40**	**0.40**	**0.44**	**0.38**	**0.41**

*Figures in parenthesis are original values

Appendix X. Effect of different herbicidal treatments on dry weight of *Anagallis arvensis* (g m^2) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	1.25 (0.6)	1.27 (0.6)	1.26 (0.6)	2.42 (4.9)	2.45 (5.0)	2.44 (5.0)	2.69 (6.2)	3.23 (9.9)	2.99 (8.1)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	1.28 (0.6)	1.26 (0.6)	1.27 (0.6)	2.26 (4.2)	2.25 (4.1)	2.26 (4.2)	2.57 (5.6)	2.99 (8.0)	2.78 (6.8)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	1.28 (0.6)	1.25 (0.6)	1.27 (0.6)	1.86 (2.5)	1.84 (2.40)	1.85 (2.5)	2.32 (4.4)	2.73 (6.5)	2.53 (5.5)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	1.24 (0.5)	1.25 (0.6)	1.25 (0.6)	2.48 (5.1)	2.56 (5.6)	2.52 (5.4)	2.90 (7.5)	3.61 (12.0)	3.26 (9.8)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	1.22 (0.5)	1.21 (0.5)	1.22 (0.5)	2.38 (4.7)	2.45 (5.0)	2.42 (4.9)	2.81 (7.0)	3.24 (9.5)	3.03 (8.3)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	1.24 (0.5)	1.25 (0.6)	1.25 (0.6)	2.32 (4.4)	2.37 (4.6)	2.35 (4.5)	2.67 (6.2)	2.96 (7.8)	2.82 (7.0)
T_7	Pyroxsulam 4.5% with surfactant	18.75	1.21 (0.5)	1.22 (0.5)	1.22 (0.5)	3.62 (5.9)	2.64 (6.0)	2.63 (6.0)	2.92 (7.5)	3.76 (13.2)	3.34 (10.4)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	1.25 (0.6)	1.28 (0.6)	1.27 (0.6)	3.48 (11.1)	3.26 (9.7)	3.37 (10.4)	3.97 (14.8)	4.74 (21.5)	4.35 (18.2)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	1.25 (0.6)	1.28 (0.6)	1.27 (0.6)	2.58 (5.7)	2.68 (6.3)	2.64 (6.0)	2.89 (7.4)	3.58 (11.9)	3.24 (9.7)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	1.29 (0.7)	1.26 (0.6)	1.28 (0.7)	1.72 (2.0)	1.78 (2.2)	1.75 (2.1)	1.93 (2.8)	1.87 (2.6)	1.90 (2.7)
T_{11}	Hand weeding twice	30 & 60 DAS	1.27 (0.6)	1.25 (0.6)	1.26 (0.6)	1.48 (1.2)	1.59 (1.5)	1.53 (1.4)	1.76 (2.1)	1.59 (1.5)	1.68 (1.8)
T_{12}	Control (weedy check)	-	1.25 (0.6)	1.25 (0.6)	1.25 (0.6)	4.67 (20.8)	5.37 (27.9)	5.04 (24.4)	5.13 (25.4)	5.55 (29.9)	5.34 (27. 7)
SEm ±			**0.02**	**0.02**	**0.02**	**0.06**	**0.12**	**0.09**	**0.15**	**0.14**	**0.15**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.18**	**0.36**	**0.27**	**0.44**	**0.43**	**0.44**

*Figures in parenthesis are original values

Appendix XI. Effect of different herbicidal treatments on dry weight of *Chenopodium album* (g m^2) in wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	1.39 (0.9)	1.45 (1.1)	1.42 (1.0)	2.87 (7.3)	3.58 (11.8)	3.23 (9.6)	3.41 (10.6)	2.97 (7.9)	3.19 (9.3)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	1.33 (0.8)	1.40 (1.0)	1.37 (0.9)	2.66 (6.1)	3.25 (9.6)	2.96 (7.9)	2.94 (7.7)	2.50 (5.3)	2.72 (6.5)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	1.35 (0.8)	1.45 (1.1)	1.40 (1.0)	2.16 (3.7)	2.67 (6.2)	2.42 (5.5)	2.76 (6.7)	2.31 (4.4)	2.53 (5.6)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	1.39 (0.9)	1.43 (1.0)	1.41 (1.0)	3.00 (8.0)	3.99 (14.9)	3.49 (11.5)	3.57 (11.8)	3.07 (8.5)	3.32 (10.2)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	1.35 (0.8)	1.39 (0.9)	1.37 (0.9)	2.83 (7.0)	3.67 (12.5)	3.25 (9.8)	3.43 (10.9)	2.99 (8.0)	3.21 (9.5)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	1.43 (1.0)	1.46 (1.1)	1.45 (1.1)	2.72 (6.4)	3.36 (10.3)	3.04 (8.4)	3.24 (9.5)	2.86 (7.3)	3.05 (8.4)
T_7	Pyroxsulam 4.5% with surfactant	18.75	1.33 (0.8)	1.39 (0.9)	1.36 (0.9)	3.25 (9.6)	3.95 (14.6)	3.60 (12.1)	3.86 (13.9)	3.50 (11.3)	3.68 (12.6)
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	1.34 (0.8)	1.41 (1.0)	1.38 (0.9)	4.42 (18.5)	5.87 (33.4)	5.14 (26.0)	5.40 (28.2)	4.56 (19.8)	4.98 (24.0)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	1.33 (0.7)	1.43 (1.0)	1.38 (0.9)	2.87 (7.3)	3.69 (12.6)	3.28 (10.0)	3.69 (12.7)	3.20 (9.2)	3.45 (11.0)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	1.41 (1.0)	1.44 (1.1)	1.43 (1.1)	1.96 (2.9)	2.33 (4.5)	2.15 (3.7)	2.57 (5.8)	2.21 (4.1)	2.39 (5.0)
T_{11}	Hand weeding twice	30 & 60 DAS	1.34 (0.8)	1.47 (1.1)	1.41 (1.0)	1.77 (2.2)	1.85 (2.5)	1.81 (2.4)	1.89 (2.6)	1.89 (2.6)	1.89 (2.6)
T_{12}	Control (weedy check)	-	1.37 (0.8)	1.45 (1.1)	1.41 (1.0)	5.47 (29.0)	7.22 (51.2)	6.35 (40.1)	6.10 (36.3)	6.51 (41.4)	6.31 (38.9)
SEm ±			**0.04**	**0.03**	**0.04**	**0.12**	**0.13**	**0.13**	**0.19**	**0.14**	**0.17**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.35**	**0.39**	**0.37**	**0.57**	**0.43**	**0.50**

*Figures in parenthesis are original values

Appendix XII. **Effect of different herbicidal treatments on dry weight of *Medicago truncatula* (g m^2) in wheat at different time intervals**

Treatment		Dose (g *a.i.*ha^{-1})	Before application			45 DAA			At harvest		
			2016-17	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.09 (3.4)	2.12 (3.5)	2.11 (3.5)	3.56 (11.7)	3.47 (11.1)	3.52 (11.4)	3.15 (9.0)	2.96 (7.8)	3.06 (8.4)
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	1.98 (2.9)	2.01 (3.1)	2.00 (3.0)	3.09 (8.6)	2.99 (8.0)	3.04 (8.3)	2.95 (7.7)	2.74 (6.5)	2.84 (7.1)
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.11 (3.4)	2.14 (3.6)	2.13 (3.5)	2.68 (6.2)	2.62 (5.9)	2.65 (6.1)	2.60 (5.8)	2.37 (4.6)	2.48 (5.2)
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.11 (3.5)	2.14 (3.6)	2.13 (3.6)	3.82 (13.6)	3.74 (13.1)	3.78 (13.4)	3.53 (11.7)	3.36 (10.4)	3.45 (11.1)
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.14 (3.6)	2.19 (3.8)	2.17 (3.7)	3.63 (12.2)	3.54 (11.6)	3.59 (11.9)	3.27 (9.7)	3.07 (8.5)	3.17 (9.1)
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.04 (3.2)	2.09 (3.4)	2.07 (3.3)	3.30 (10.0)	3.22 (9.4)	3.26 (9.7)	3.05 (8.4)	2.85 (7.2)	2.95 (7.8)
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.06 (3.3)	2.11 (3.4)	2.09 (3.4)	3.78 (13.3)	3.70 (12.8)	3.74 (13.1)	3.66 (12.4)	3.48 (11.2)	3.57 (11.8)
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	1.97 (2.9)	1.98 (2.9)	1.98 (2.9)	5.30 (27.3)	4.82 (22.3)	5.06 (24.8)	4.79 (22.0)	4.21 (16.7)	4.50 (19.4)
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.04 (3.2)	2.05 (3.2)	2.05 (3.2)	3.72 (12.9)	3.65 (12.3)	3.69 (12.6)	3.35 (10.3)	3.17 (9.1)	3.26 (9.7)
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2.07 (3.3)	2.08 (3.4)	2.08 (3.4)	2.28 (4.2)	2.22 (4.0)	2.25 (4.1)	2.25 (4.1)	1.97 (2.9)	2.11 (3.5)
T_{11}	Hand weeding twice	30 & 60 DAS	2.08 (3.3)	2.10 (3.4)	2.09 (3.4)	1.87 (2.5)	1.73 (2.0)	1.80 (2.3)	1.80 (2.3)	1.55 (1.4)	1.68 (1.9)
T_{12}	Control (weedy check)	-	2.13 (3.5)	2.16 (3.7)	2.15 (3.6)	6.99 (48.1)	6.31 (38.9)	6.65 (43.5)	7.45 (55.2)	6.10 (36.4)	6.78 (45.8)
SEm ±			**0.06**	**0.06**	**0.06**	**0.16**	**0.15**	**0.16**	**0.25**	**0.16**	**0.21**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.47**	**0.43**	**0.45**	**0.74**	**0.49**	**0.61**

*Figures in parenthesis are original values

Appendix XIII. Effect of different herbicidal treatments on plant population (m^2) of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	15 DAS			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	198.9	203.1	201.0	196.8	196.3	196.6
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	199.9	207.0	203.4	198.1	197.0	197.6
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	202.0	205.2	203.6	198.9	197.8	198.3
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	196.9	201.3	199.1	195.2	195.7	195.4
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	198.7	202.2	200.4	194.9	196.3	195.6
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	196.4	201.3	198.9	188.8	196.3	192.6
T_7	Pyroxsulam 4.5% with surfactant	18.75	197.6	204.7	201.1	197.8	196.4	197.1
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	200.9	205.9	203.4	199.8	196.9	198.3
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	197.4	201.0	199.2	196.4	197.1	196.8
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	196.9	201.1	199.0	195.8	196.7	196.2
T_{11}	Hand weeding twice	30 & 60 DAS	195.1	201.3	198.2	194.7	197.7	196.2
T_{12}	Control (weedy check)	-	198.7	201.8	200.2	197.0	197.0	197.0
SEm ±			**2.42**	**2.6**	**2.5**	**2.81**	**0.41**	**1.61**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*Figures in parenthesis are original values

Appendix XIV. Effect of different herbicidal treatments on plant height (cm) of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	28.9	27.0	27.9	89.2	89.7	89.43	88.1	87.4	87.7
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	28.8	26.9	27.8	91.0	91.2	91.08	89.5	89.2	89.3
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	29.1	28.2	28.7	93.7	92.4	93.07	91.8	91.9	91.8
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	29.6	28.4	29.0	87.3	87.9	87.59	86.0	86.9	86.5
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	29.5	29.7	29.6	88.9	88.9	88.91	87.6	88.3	87.9
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	30.7	31.7	31.2	90.2	90.6	90.40	88.6	89.8	89.2
T_7	Pyroxsulam 4.5% with surfactant	18.75	29.7	29.7	29.7	87.7	87.0	87.33	86.2	85.8	86.0
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	29.4	28.7	29.1	88.1	86.4	87.23	85.8	85.5	85.6
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	30.9	30.2	30.6	87.4	86.6	87.00	86.5	86.3	86.4
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	30.0	30.4	30.2	86.5	85.7	86.08	84.7	84.8	84.7
T_{11}	Hand weeding twice	30 & 60 DAS	31.4	31.4	31.4	94.5	93.3	93.92	92.0	92.8	92.4
T_{12}	Control (weedy check)	-	30.4	30.1	30.3	85.2	82.3	83.75	84.1	81.1	82.6
SEm ±			**0.66**	**0.8**	**0.7**	**0.71**	**1.17**	**0.94**	**0.70**	**0.36**	**0.53**
CD (P=0.05)			**NS**	**NS**	**NS**	**2.10**	**3.44**	**2.77**	**2.07**	**1.05**	**1.56**

*Figures in parenthesis are original values

Appendix XV. Effect of different herbicidal treatments on tillers per meter row length of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA			At harvest		
			2016-17	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**	**2016-17**	**201-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	246.3	245.0	245.7	280.0	278.7	279.3	304.7	300.7	302.7
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	246.7	247.7	247.2	285.7	284.3	285.0	311.7	307.7	309.7
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	249.7	248.3	249.0	290.3	288.7	289.5	318.3	314.3	316.3
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	247.3	247.7	247.5	275.3	274.0	274.7	299.0	295.0	297.0
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	253.0	256.7	254.8	280.0	278.7	279.3	303.3	299.3	301.3
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	244.0	243.0	243.5	282.3	280.7	281.5	307.3	303.3	305.3
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	251.0	252.3	251.7	273.7	272.3	273.0	293.3	289.3	291.3
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	250.7	253.3	252.0	272.3	270.7	271.5	296.3	292.3	294.3
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	250.7	251.3	251.0	278.0	277.0	277.5	300.0	296.0	298.0
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% **with surfactant**	47.93	248.0	247.3	247.7	265.7	266.3	266.0	273.0	275.7	274.3
T_{11}	Hand weeding twice	30 & 60 DAS	249.0	249.0	249.0	295.0	293.7	294.3	322.0	318.0	320.0
T_{12}	Control (weedy check)	-	249.3	250.7	250.0	264.0	264.0	264.0	272.7	269.7	271.2
SEm ±			**1.7**	**3.2**	**2.4**	**1.7**	**2.0**	**1.9**	**1.9**	**1.9**	**1.9**
CD (P=0.05)			**NS**	**NS**	**NS**	**5.0**	**6.0**	**5.5**	**5.6**	**5.7**	**5.7**

*Figures in parenthesis are original values

Appendix XVI. Effect of different herbicidal treatments on crop dry weight per meter row length of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	201-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	48.4	49.7	49.1	1296.1	1272.3	1284.2	1580.9	1577.2	1579.1
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	47.3	51.3	49.3	1318.6	1306.7	1312.6	1607.4	1603.7	1605.6
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	51.2	55.9	53.5	1344.7	1330.1	1337.4	1625.6	1616.9	1621.3
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	45.2	49.2	47.2	1271.0	1238.5	1254.8	1546.1	1546.1	1546.1
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	45.7	50.3	48.0	1285.7	1265.4	1275.5	1572.8	1585.4	1579.1
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	45.8	51.2	48.5	1313.0	1277.1	1295.1	1610.0	1610.0	1610.0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	44.8	50.7	47.7	1226.0	1211.8	1218.9	1511.0	1511.0	1511.0
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	48.9	51.5	50.2	1220.0	1217.3	1218.7	1500.4	1497.8	1499.1
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	50.5	63.8	57.2	1229.6	1227.7	1228.6	1503.7	1499.1	1501.4
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	45.4	54.6	50.0	1209.7	1202.1	1205.9	1463.7	1451.1	1457.4
T_{11}	Hand weeding twice	30 & 60 DAS	46.2	50.6	48.4	1366.6	1341.7	1354.2	1674.3	1653.8	1664.0
T_{12}	Control (weedy check)	-	45.7	48.4	47.0	1189.2	1185.3	1187.3	1382.6	1344.7	1363.7
SEm ±			**1.90**	**4.06**	**2.98**	**18.8**	**24.4**	**21.6**	**17.3**	**17.1**	**17.2**
CD (P=0.05)			**NS**	**NS**	**NS**	**53.2**	**71.9**	**62.6**	**50.9**	**50.4**	**50.7**

*Figures in parenthesis are original values

Appendix XVII. Effect of different herbicidal treatments on leaves plant^{-1} of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	7.9	7.7	7.8	13.8	13.3	13.6	9.2	9.2	9.2
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	10.3	8.8	9.6	14.3	13.4	13.9	9.4	8.9	9.2
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	8.8	9.0	8.9	14.5	13.3	13.9	9.1	9.2	9.2
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	8.7	9.2	9.0	13.4	13.4	13.4	9.9	9.3	9.6
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	9.0	8.9	9.0	13.5	14.0	13.8	9.3	9.0	9.2
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	8.1	8.3	8.2	13.8	14.5	14.2	9.7	9.2	9.5
T_7	Pyroxsulam 4.5% with surfactant	18.75	7.3	8.4	7.9	12.8	13.8	13.3	9.4	9.1	9.3
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	6.8	7.5	7.2	14.8	14.8	14.8	9.8	9.3	9.6
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	9.0	9.3	9.2	14.7	14.7	14.7	9.5	9.1	9.3
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	7.6	8.3	8.0	13.6	12.6	13.1	9.5	9.6	9.6
T_{11}	Hand weeding twice	30 & 60 DAS	7.5	8.8	8.2	14.4	14.2	14.3	9.8	9.7	9.8
T_{12}	Control (weedy check)	-	7.3	10.3	8.8	13.0	13.5	13.3	9.2	9.6	9.4
SEm ±			**0.70**	**0.59**	**0.65**	**0.65**	**0.95**	**0.80**	**0.20**	**0.22**	**0.21**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*Figures in parenthesis are original values

Appendix XVIII. Effect of different herbicidal treatments on leaf area of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	79.5	80.3	79.9	244.7	236.62	240.6
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	76.6	77.1	76.9	259.0	247.79	253.4
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	78.0	78.8	78.4	267.8	267.63	267.7
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	79.8	81.1	80.5	238.7	232.37	235.5
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	78.4	78.8	78.6	243.8	241.72	242.8
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	78.1	79.5	78.8	250.4	251.35	250.9
T_7	Pyroxsulam 4.5% with surfactant	18.75	78.6	80.1	79.3	232.5	231.41	231.9
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	78.0	78.3	78.1	230.1	230.03	230.1
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	77.3	79.3	78.3	233.5	232.47	233.0
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	73.1	75.5	74.3	229.6	230.17	229.9
T_{11}	Hand weeding twice	30 & 60 DAS	79.0	79.4	79.2	273.0	275.28	274.2
T_{12}	Control (weedy check)	-	81.2	81.4	81.3	227.3	227.29	227.3
SEm ±			**3.31**	**3.14**	**3.23**	**3.06**	**1.52**	**2.29**
CD (P=0.05)			**NS**	**NS**	**NS**	**9.03**	**4.48**	**6.76**

*Figures in parenthesis are original values

Appendix XIX. Effect of different herbicidal treatments on leaf area index of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	1.50	1.43	1.47	4.35	4.21	4.28
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	1.40	1.37	1.39	4.60	4.41	4.51
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	1.50	1.40	1.45	4.76	4.76	4.76
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	1.40	1.44	1.42	4.24	4.13	4.19
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	1.40	1.40	1.40	4.33	4.3	4.32
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	1.30	1.41	1.36	4.45	4.47	4.46
T_7	Pyroxsulam 4.5% with surfactant	18.75	1.30	1.42	1.36	4.13	4.11	4.12
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	1.40	1.39	1.40	4.09	4.09	4.09
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	1.40	1.41	1.41	4.15	4.13	4.14
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant	47.93	1.40	1.34	1.37	4.08	4.09	4.09
T_{11}	Hand weeding twice	30 & 60 DAS	1.30	1.41	1.36	4.85	4.89	4.87
T_{12}	Control (weedy check)	-	1.40	1.45	1.43	4.04	4.04	4.04
SEm ±			**0.06**	**0.06**	**0.06**	**0.06**	**0.03**	**0.05**
CD (P=0.05)			**NS**	**NS**	**NS**	**0.16**	**0.08**	**0.12**

*Figures in parenthesis are original values

Appendix XXI. Effect of different herbicidal treatments on chlorophyll content of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 DAS			90 DAA		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	43.6	43.8	43.7	30.2	31.3	30.7
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	43.7	43.7	43.7	30.3	31.2	30.8
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	44.1	44.2	44.2	30.4	32.1	31.2
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	43.6	43.6	43.6	30.2	31.3	30.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	43.6	43.7	43.7	30.3	31.4	30.9
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	43.7	43.9	43.8	30.2	31.3	30.7
T_7	Pyroxsulam 4.5% with surfactant	18.75	43.2	43.1	43.2	30.2	31.2	30.7
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	43.6	43.7	43.7	30.3	31.4	30.8
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	43.6	43.5	43.6	30.2	31.3	30.7
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	43.5	43.8	43.7	30.3	31.3	30.8
T_{11}	Hand weeding twice	30 & 60 DAS	43.8	43.6	43.7	30.2	31.9	31.0
T_{12}	Control (weedy check)	-	43.9	43.6	43.8	30.3	31.3	30.8
SEm ±			**0.27**	**0.18**	**0.23**	**0.11**	**0.23**	**0.17**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*Figures in parenthesis are original values

Appendix XXII. Effect of different herbicidal treatments on RGR (g g-^{1}day^{-1}) of wheat at different time intervals

Treatment		Dose (g *a.i.*ha^{-1})	30 – 60			60 – 90		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	0.09854	0.09631	0.09743	0.0160	0.0160	0.0160
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	0.10116	0.09771	0.09944	0.0170	0.0160	0.0165
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	0.10209	0.10133	0.10171	0.0160	0.0160	0.0160
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	0.09936	0.0993	0.09933	0.0160	0.0170	0.0165
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	0.09971	0.09677	0.09824	0.0170	0.0160	0.0165
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	0.10048	0.09882	0.09965	0.0170	0.0160	0.0165
T_7	Pyroxsulam 4.5% with surfactant	18.75	0.0985	0.09654	0.09752	0.0170	0.0170	0.0170
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	0.09639	0.09426	0.09533	0.0170	0.0170	0.0170
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	0.096	0.09353	0.09477	0.0160	0.0170	0.0165
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	0.09685	0.09328	0.09507	0.0160	0.0160	0.0160
T_{11}	Hand weeding twice	30 & 60 DAS	0.10576	0.10445	0.10511	0.0160	0.0160	0.0160
T_{12}	Control (weedy check)	-	0.09727	0.0955	0.09639	0.0150	0.0150	0.0150
SEm ±			**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**
CD (P=0.05)			**0.003**	**0.004**	**0.004**	**0.001**	**0.001**	**0.001**

*Figures in parenthesis are original values

Appendix XXIII. Effect different herbicidal treatments on CGR (g m^{-2} day^{-1}) of wheat at different time interval

Treatment		Dose (g *a.i.*ha^{-1})	30 – 60			60 – 90		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	26.0	26.23	26.1	17.4	16.93	17.2
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	26.6	26.79	26.7	18.0	17.45	17.7
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	27.8	27.83	27.8	18.3	17.5	17.9
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	25.3	25.13	25.2	17.1	17.18	17.1
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	25.7	26	25.9	17.3	16.98	17.2
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	26.4	26.73	26.6	17.6	17.29	17.4
T_7	Pyroxsulam 4.5% with surfactant	18.75	24.6	24.63	24.6	16.8	16.74	16.7
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	24.3	24.38	24.3	16.7	16.69	16.7
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	25.0	24.32	24.6	16.8	17.28	17.0
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	24.3	24.2	24.2	16.2	16.14	16.2
T_{11}	Hand weeding twice	30 & 60 DAS	28.8	28.87	28.8	18.4	18.24	18.3
T_{12}	Control (weedy check)	-	23.9	23.95	23.9	14.7	14.5	14.6
SEm ±			**0.25**	**0.27**	**0.26**	**0.23**	**0.28**	**0.26**
CD (P=0.05)			**0.74**	**0.79**	**0.77**	**0.68**	**0.83**	**0.76**

*Figures in parenthesis are original values

Appendix XXIV. Effect of different herbicide treatments on length of ear head and grains ear head^{-1} of wheat at harvest

Treatment		Dose (g *a.i.*ha^{-1})	Length of ear head			Grains ear head^{-1}		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	9.0	8.9	9.0	49.9	48.9	49.4
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	9.3	9.1	9.2	50.5	49.8	50.2
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	9.4	9.3	9.4	51.0	50.8	50.9
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	8.7	8.6	8.7	49.5	48.1	48.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	8.8	8.8	8.8	50.2	49.3	49.8
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	9.0	9.0	9.0	50.7	49.6	50.1
T_7	Pyroxsulam 4.5% with surfactant	18.75	8.7	8.7	8.7	49.2	46.5	47.9
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	8.7	8.8	8.7	49.2	46.8	48.0
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	8.8	8.7	8.8	49.0	44.3	46.7
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	8.3	8.3	8.3	48.8	45.7	47.3
T_{11}	Hand weeding twice	30 & 60 DAS	9.6	9.6	9.6	51.4	50.8	51.1
T_{12}	Control (weedy check)	-	7.8	7.8	7.8	47.4	43.3	45.4
SEm ±			**0.07**	**0.09**	**0.08**	**0.12**	**0.44**	**0.28**
CD (P=0.05)			**0.21**	**0.26**	**0.24**	**0.36**	**1.31**	**0.84**

*Figures in parenthesis are original values

Appendix XXV. Effect of different herbicidal treatments on effective tillers meter^{-1} row length and test weight of wheat at harvest

Treatment		Dose (g *a.i.*ha^{-1})	Effective tillers/m row length			Test weight		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	285.33	284.30	284.82	43.70	43.43	43.57
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	290.00	288.00	289.00	44.47	44.18	44.33
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	297.67	296.00	296.84	45.14	45.17	45.16
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	280.00	278.30	279.15	43.34	43.20	43.27
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	285.67	283.70	284.69	43.84	43.53	43.69
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	293.00	290.70	291.85	44.19	43.80	44.00
T_7	Pyroxsulam 4.5% with surfactant	18.75	274.00	272.30	273.15	43.14	43.00	43.07
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	272.00	267.30	269.65	43.00	43.09	43.05
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	275.00	273.70	274.35	43.23	43.21	43.22
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	266.67	264.70	265.69	43.03	43.14	43.09
T_{11}	Hand weeding twice	30 & 60 DAS	304.00	301.70	302.85	45.22	45.38	45.30
T_{12}	Control (weedy check)	-	254.00	251.00	252.50	42.00	43.02	42.51
SEm ±			**3.37**	**3.86**	**3.62**	**0.25**	**0.26**	**0.26**
CD (P=0.05)			**9.95**	**11.40**	**10.68**	**0.75**	**0.77**	**0.76**

*Figures in parenthesis are original values

Appendix XXVI. Effect of different herbicidal treatments on harvest index and weed index of wheat at harvest

Treatment		Dose (g *a.i.*ha^{-1})	Harvest index			Weed index		
			2016-17	2017-18	mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	40.5	41.6	41.1	8.5	8.3	8.4
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	41.2	41.9	41.6	5.4	6.8	6.1
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	42.1	42.6	42.4	1.3	2.8	2.1
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	40.1	40.7	40.4	11.4	11.8	11.6
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	40.7	41.1	40.9	9.5	9.8	9.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	41.3	41.9	41.6	6.0	6.3	6.2
T_7	Pyroxsulam 4.5% with surfactant	18.75	40.0	40.2	40.1	14.4	12.3	13.4
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	40.1	40.2	40.2	14.3	12.5	13.4
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	40.1	40.3	40.2	13.6	12	12.8
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	39.8	39.7	39.8	15.0	14.5	14.8
T_{11}	Hand weeding twice	30 & 60 DAS	42.2	42.9	42.6	0.0	0	0.0
T_{12}	Control (weedy check)	-	39.3	38.9	39.1	36.7	34.5	35.6
SEm ±			**0.30**	**0.23**	**0.27**	**0.71**	**0.76**	**0.74**
CD (P=0.05)			**0.90**	**0.69**	**0.80**	**2.10**	**2.24**	**2.17**

*Figures in parenthesis are original values

Appendix XXVII. Effect of different herbicidal treatments on pH, OC and EC before experiment of wheat field

Treatment		Dose (g *a.i.*ha^{-1})	pH			EC			OC		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	201-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	7.14	7.10	7.12	0.28	0.29	0.29	0.53	0.54	0.54
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	7.18	7.17	7.18	0.29	0.30	0.30	0.53	0.53	0.53
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	7.22	7.20	7.21	0.29	0.29	0.29	0.54	0.54	0.54
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	7.15	7.18	7.17	0.30	0.29	0.30	0.53	0.54	0.54
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	7.14	7.17	7.16	0.30	0.30	0.30	0.54	0.55	0.55
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	7.18	7.19	7.19	0.28	0.29	0.29	0.54	0.53	0.54
T_7	Pyroxsulam 4.5% with surfactant	18.75	7.08	7.11	7.10	0.28	0.28	0.28	0.54	0.54	0.54
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	7.19	7.20	7.20	0.29	0.30	0.30	0.54	0.55	0.55
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	7.15	7.17	7.16	0.29	0.30	0.30	0.53	0.54	0.54
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	7.09	7.11	7.10	0.29	0.29	0.29	0.55	0.54	0.55
T_{11}	Hand weeding twice	30 & 60 DAS	7.15	7.17	7.16	0.29	0.30	0.30	0.54	0.53	0.54
T_{12}	Control (weedy check)	-	7.19	7.16	7.18	0.29	0.29	0.29	0.53	0.53	0.53
SEm ±			**0.27**	**0.18**	**0.23**	**0.24**	**0.57**	**0.41**	**0.11**	**0.23**	**0.17**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*Figures in parenthesis are original values

Appendix XXVIII. Effect of different herbicidal treatments on pH, OC and EC after experiment of wheat field

Treatment		Dose (g *a.i*.ha^{-1})	pH			EC			OC		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	7.19	7.21	7.20	0.29	0.30	0.30	0.54	0.53	0.54
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	7.11	7.13	7.12	0.28	0.29	0.29	0.54	0.54	0.54
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	7.14	7.16	7.15	0.28	0.31	0.30	0.54	0.53	0.54
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	7.19	7.18	7.19	0.31	0.30	0.31	0.53	0.53	0.53
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	7.10	7.12	7.11	0.28	0.29	0.29	0.55	0.54	0.55
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	7.10	7.13	7.12	0.29	0.30	0.30	0.54	0.54	0.54
T_7	Pyroxsulam 4.5% with surfactant	18.75	7.20	7.15	7.18	0.28	0.29	0.29	0.53	0.54	0.54
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	7.18	7.20	7.19	0.28	0.29	0.29	0.53	0.53	0.53
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	7.14	7.16	7.15	0.29	0.30	0.30	0.53	0.54	0.54
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	7.15	7.17	7.16	0.29	0.29	0.29	0.54	0.54	0.54
T_{11}	Hand weeding twice	30 & 60 DAS	7.25	7.19	7.22	0.30	0.31	0.31	0.53	0.55	0.54
T_{12}	Control (weedy check)	-	7.11	7.13	7.12	0.30	0.29	0.30	0.54	0.54	0.54
SEm ±			**0.27**	**0.18**	**0.23**	**0.24**	**0.57**	**0.41**	**0.11**	**0.23**	**0.17**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value			**7.5**			**0.29**			**0.54**		

*Figures in parenthesis are original values

Appendix XXIX. Effect of different herbicidal treatments on uptake of nitrogen by grain and straw of wheat

Treatment		Dose (g *a.i.*ha^{-1})	Nitrogen by grain (kg ha^{-1})			Nitrogen by straw (kg ha^{-1})			Total nitrogen (kg ha^{-1})		
			2016-17	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	92.53	92.61	93	31.62	30.09	31	124.05	122.70	123
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	96.37	94.75	96	33.27	31.45	32	129.12	126.20	128
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	102.07	99.32	101	33.56	31.79	33	135.91	131.11	134
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	87.81	88.82	88	30.25	29.56	30	117.97	118.38	118
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	91.13	91.01	91	30.54	30.55	31	122.2	121.56	122
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	95.60	95.00	95	32.29	31.09	32	127.87	126.09	127
T_7	Pyroxsulam 4.5% with surfactant	18.75	83.84	87.92	86	29.96	29.39	30	113.57	117.31	115
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	84.94	87.74	86	30.56	29.51	30	114.94	117.25	116
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	86.18	89.03	88	30.66	29.39	30	116.4	118.42	117
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	83.93	86.55	85	30.14	28.83	29	114.05	115.38	115
T_{11}	Hand weeding twice	30 & 60 DAS	105.05	102.52	104	34.62	33.3	34	139.88	135.82	138
T_{12}	Control (weedy check)	-	62.45	66.40	64	23.38	22.93	23	84.89	89.33	87
SEm ±			**0.92**	**0.54**	**0.73**	0.38	0.28	0.33	0.75	0.54	0.65
CD (P=0.05)			**2.71**	**1.59**	**2.15**	1.12	0.83	0.98	2.20	1.59	1.90

*Figures in parenthesis are original values

Appendix XXX. Effect of different herbicidal treatments on uptake of phosphorus by grain and straw of wheat

Treatment		Dose (g *a.i.*ha^{-1})	Phosphorus by grain (kg ha^{-1})			Phosphorus by straw (kg ha^{-1})			Total Phosphorus (kg ha^{-1})		
			2016-17	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**	**2016-17**	**201-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	19.65	19.39	19.52	7.54	7.12	7.33	27.19	26.51	27
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	20.63	20.01	20.32	7.80	7.37	7.59	28.43	27.38	28
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	21.85	21.2	21.53	9.19	8.75	8.97	31.04	29.95	30
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	19.32	18.94	19.13	6.56	6.28	6.42	25.88	25.22	26
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	19.87	19.52	19.70	7.17	6.92	7.05	27.04	26.44	27
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	20.64	20.28	20.46	7.51	7.19	7.35	28.15	27.47	28
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	18.8	18.98	18.89	7.01	7.01	7.01	25.81	25.99	26
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	18.55	18.66	18.61	6.76	6.77	6.77	25.31	25.43	25
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	19.12	19.18	19.15	7.02	7.00	7.01	26.14	26.18	26
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	18.66	18.5	18.58	7.00	6.97	6.99	25.66	25.47	26
T_{11}	Hand weeding twice	30 & 60 DAS	22.47	22.14	22.31	10.63	10.19	10.41	33.10	32.33	33
T_{12}	Control (weedy check)	-	11.93	14.09	13.01	4.83	5.04	4.94	16.76	19.13	18
SEm ±			**0.37**	**0.31**	**0.34**	**0.40**	**0.41**	**o.41**	**0.46**	**0.50**	**0.48**
CD (P=0.05)			**1.09**	**0.92**	**1.01**	**1.18**	**1.19**	**1.19**	**1.35**	**1.46**	**1.41**

*Figures in parenthesis are original values

Appendix XXXI. Effect of different herbicidal treatments on uptake of potash by grain and straw of wheat

Treatment		Dose (g *a.i.*ha^{-1})	Potash by grain (kg ha^{-1})			Potash by straw (kg ha^{-1})			Total Potash (kg ha^{-1})		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	23.59	23.27	23.43	65.47	61.81	63.64	89.06	85.08	87
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	24.85	24.10	24.48	69.73	65.89	67.81	94.58	89.99	92
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	26.9	26.09	26.50	75.32	71.74	73.53	102.22	97.83	100
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	22.68	22.24	22.46	64.68	61.94	63.31	87.36	84.18	86
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	23.46	23.05	23.26	65.19	63.00	64.10	88.65	86.05	87
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	24.83	24.40	24.62	67.61	64.71	66.16	92.44	89.11	91
T_7	Pyroxsulam 4.5% with surfactant	18.75	21.91	22.12	22.02	62.01	62.04	62.03	83.92	84.16	84
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	21.94	22.08	22.01	59.8	59.85	59.83	81.74	81.93	82
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	22.69	22.76	22.73	58.1	57.94	58.02	80.79	80.70	81
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	21.75	21.57	21.66	57.07	56.82	56.95	78.82	78.39	79
T_{11}	Hand weeding twice	30 & 60 DAS	27.09	26.69	26.89	76	72.88	74.44	103.09	99.57	101
T_{12}	Control (weedy check)	-	16.21	16.53	16.37	47.78	49.59	48.69	63.99	66.12	65
SEm ±			0.33	0.30	0.32	1.60	1.93	1.77	1.89	1.85	1.87
CD (P=0.05)			0.98	0.89	0.94	4.71	5.68	5.20	5.59	5.46	5.53

*Figures in parenthesis are original values

Appendix XXXII. Effect of different herbicidal treatments on protein content (%) and protein yield (kg ha^{-1}) of wheat

Treatment		Dose (g *a.i.*ha^{-1})	Protein content (%)			Protein yield (kg ha^{-1})		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	12.94	12.94	12.94	578	579	579
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	12.63	13.02	12.83	602	592	597
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	13.06	13.08	13.07	638	621	629
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	12.5	12.9	12.70	549	555	552
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	13.13	12.92	13.03	570	569	569
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	12.75	12.98	12.87	598	594	596
T_7	Pyroxsulam 4.5% with surfactant	18.75	12.31	12.83	12.57	524	550	537
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	12.5	12.83	12.67	531	548	540
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	12.75	12.96	12.86	539	556	548
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	12.38	12.96	12.67	525	541	533
T_{11}	Hand weeding twice	30 & 60 DAS	13.31	13.13	13.22	657	641	649
T_{12}	Control (weedy check)	-	12.44	12.83	12.64	390	411	400
SEm ±			**0.09**	**0.05**	**0.07**	**5.72**	**4.29**	**5.01**
CD (P=0.05)			**0.27**	**0.14**	**0.21**	**16.88**	**12.65**	**14.77**

*Figures in parenthesis are original values

Appendix XXXIII. Effect of different herbicidal treatments on biological yield, grain yield and straw yield (kg ha^{-1}) of wheat

Treatment		Dose (g *a.i.*ha^{-1})	Biological Yield kg ha^{-1}			Straw yield kg ha^{-1}			Grain yield kg ha^{-1}		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	201-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	11193	10760	10977	6658	6286	6472	4536	4474	4505
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	11370	10862	11116	6683	6314	6499	4687	4548	4618
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	11614	11145	11380	6723	6400	6562	4891	4745	4818
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	10947	10582	10765	6556	6277	6417	4391	4305	4348
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	11001	10703	10852	6519	6299	6409	4482	4404	4443
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	11286	10919	11103	6630	6345	6488	4655	4575	4615
T_7	Pyroxsulam 4.5% with surfactant	18.75	10612	10656	10634	6371	6374	6373	4241	4282	4262
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	10585	10618	10602	6338	6345	6342	4247	4273	4260
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	10666	10660	10663	6385	6366	6376	4281	4294	4288
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	10575	10509	10542	6364	6334	6349	4211	4174	4193
T_{11}	Hand weeding twice	30 & 60 DAS	11741	11389	11565	6786	6507	6647	4955	4882	4919
T_{12}	Control (weedy check)	-	7980	8225	8103	4842	5026	4934	3138	3200	3169
SEm ±			**39.66**	**52.83**	**46.25**	**37.83**	**32.70**	**35.27**	**34.14**	**35.97**	**35.06**
CD (P=0.05)			**117.06**	**155.96**	**136.51**	**111.67**	**96.52**	**104.10**	**100.89**	**106.18**	**103.54**

*Figures in parenthesis are original values

Appendix XXIV. (A). Common cost of cultivation per hectare area basis (ecluding cost of treatments)

S. No.	Particulars	Input (ha^{-1})	Unit cost^{-1} (₹)	Cost (₹ ha^{-1})
A	**Land preparation**			
I	Harrowing with cultivator	One pass	1250 $pass^{-1}$	1250
II	Harrowing with disc	two pass	1250 $pass^{-1}$	2500
II	Leveling	One pass	400 $pass^{-1}$	400
IV	Preparation of drainage channel	One pass	625 $pass^{-1}$	
B	**Seed and sowing**			
I	Cost of seed	100 kg ha^{-1}	(30 kg^{-1})	3200
II	Seed treatment with Bavistin	250 kg^{-1}	800 kg ha^{-1}	200
II	Seed treatment charges	1 man days	200 man^{-1} day^{-1}	200
IV	Sowing charges	10 man days	200 man^{-1} day^{-1}	2000
C	**Fertilizer**			
I	Cost of fertilizer			
	N through urea	120 kg N	13.00 kg^{-1}	1565
	P_2O_5 though SSP	60 kg P_2O_5	37 kg^{-1}	2213
	K2O though MOP	40 kg K_2O	28 kg^{-1}	1120
II	Cost of application	2 man days	200 /man/day	
D	Irrigation (including application charge)	Five	600/irrigation	3000
E	Harvesting, bundling and transporting	30 man days	200/man/day	6000
F	Threshing and winnowing	10 man days	200/man/day	2000
G	Land rent	6 month	10000/year	5000
	Total cost (excluding cost c)			**30648**

(B). Estimation of variable cost of cultivation due to various weed control treatments (on per hectare area basis)

Treatment	Dose *a.i.* g ha^{-1}	Commercial Dose (g ha^{-1})	Unit price (₹ kg^{-1})	Cost (₹ ha^{-1}) Including application charges (Rs 400 ha^{-1})
Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	1095	15000	1495
Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	1320	15000	1720
Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	1545	15000	1945
Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	975	15000	1375
Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	1200	15000	1600
Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	1425	15000	1825
Pyroxsulam 4.5% with surfactant	18.75	770		1170
Halauxifen-methyl 10.42% with surfactant	5.21	820		1220
Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	645		1045
Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	2670	16000	3070
Hand weeding twice	30 & 60 DAS	6000		
Control	-	-		

(C). Economic analysis of different treatments in wheat (on per hectare area basis)

Treatment		Dose (g *a.i.*ha^{-1})	Common expenditure (₹ ha^{-1})			Under herbicidal treatment (₹ ha^{-1})			Total cost of cultivation (₹ ha^{-1})		
			2016-17	2017-18	mean	2016-17	2017-18	Mean	2016-17	201-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	30648	30648	30648	1495	1495	1495	32143	32143	32143
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	30648	30648	30648	1720	1720	1720	32368	32368	32368
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	30648	30648	30648	1945	1945	1945	32593	32593	32593
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	30648	30648	30648	1375	1375	1375	32023	32023	32023
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	30648	30648	30648	1600	1600	1600	32248	32248	32248
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	30648	30648	30648	1825	1825	1825	32473	32473	32473
T_7	Pyroxsulam 4.5% with surfactant	18.75	30648	30648	30648	1170	1170	1170	31818	31818	31818
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	30648	30648	30648	1220	1220	1220	31868	31868	31868
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	30648	30648	30648	1045	1045	1045	31693	31693	31693
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant	47.93	30648	30648	30648	3070	3070	3070	33718	33718	33718
T_{11}	Hand weeding twice	30 & 60 DAS	30648	30648	30648	6000	6000	6000	36648	36648	36648
T_{12}	Control (weedy check)	-	30648	30648	30648	0	0	0	30648	30648	30648

(D). Economic analysis of different treatments in wheat during *Rabi* 2016-17 and 2017-18

Treatment		Dose (g *a.i.*ha^{-1})	Gross return (₹ ha^{-1})			Net return (₹ ha^{-1})			B:C ratio		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	201-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	92016	90196	91106	59873	58053	58963	2.9	2.8	2.8
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	94685	91536	93111	62317	59168	60743	2.9	2.8	2.9
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	98305	95126	96716	65712	62533	64123	3.0	2.9	3.0
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	89296	87246	88271	57273	55223	56248	2.8	2.7	2.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	90801	89007	89904	58553	56759	57656	2.8	2.8	2.8
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	94024	92066	93045	61551	59593	60572	2.9	2.8	2.9
T_7	Pyroxsulam 4.5% with surfactant	18.75	86323	87041	86682	54505	55223	54864	2.7	2.7	2.7
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	86361	86827	86594	54493	54959	54726	2.7	2.7	2.7
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	87045	87233	87139	55352	55540	55446	2.8	2.8	2.8
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant	47.93	85789	85087	85438	52071	51369	51720	2.5	2.5	2.5
T_{11}	Hand weeding twice	30 & 60 DAS	99541	97717	98629	62893	61069	61981	2.7	2.7	2.7
T_{12}	Control (weedy check)	-	64128	65572	64850	33480	34924	34202	2.1	2.1	2.1

Appendix XXXV. Effect of different herbicide treatments on germination (%) succeeding soybean crop

Treatment		Dose (g *a.i.*ha^{-1})	Seed Germination (%)		
			2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	85	86	85.50
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	87	86	86.50
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	85	88	86.50
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	86	85	85.50
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	87	88	87.50
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	86	86	86.00
T_7	Pyroxsulam 4.5% with surfactant	18.75	86	87	86.50
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	85	86	85.50
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	85	86	85.50
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant	47.93	89	87	88.00
T_{11}	Hand weeding twice	30 & 60 DAS	85	86	85.50
T_{12}	Control (weedy check)	-	87	87	87.00

Appendix XXXVI. Effect of different herbicide treatments on plant population in succeeding soybean crop at 15 DAS and at harvest

Treatment		Dose (g *a.i.*ha^{-1})	Plant population at 15 DAS			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	48.87	48.87	48.9	48.00	47.80	47.9
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	48.23	48.23	48.2	47.77	47.61	47.7
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	49.39	49.39	49.4	47.87	48.27	48.1
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	49.87	49.87	49.9	48.50	48.50	48.5
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	48.47	48.47	48.5	47.79	47.79	47.8
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	48.31	48.31	48.3	47.88	47.88	47.9
T_7	Pyroxsulam 4.5% with surfactant	18.75	50.11	50.11	50.1	49.00	49.00	49.0
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	48.89	48.89	48.9	47.23	47.23	47.2
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	46.87	46.87	46.9	45.32	45.32	45.3
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	48.23	49.39	48.8	47.94	48.27	48.1
T_{11}	Hand weeding twice	30 & 60 DAS	48.74	48.65	48.7	47.13	47.57	47.4
T_{12}	Control (weedy check)	-	49.74	48.93	49.3	48.12	47.79	48.0
SEm ±			**1.23**	**1.26**	**1.2**	**2.12**	**2.18**	**2.2**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

*Figures in parenthesis are original values

Appendix XXXVII. Effect of different herbicidal treatments on yield attributes in succeeding soybean crop at harvest

Treatment		Dose (g *a.i.*ha^{-1})	Pods plant^{-1}			Seeds pod^{-1}			Seed index		
			2016-17	**2017-18**	**Mean**	**2016-17**	**2017-18**	**Mean**	**2016-17**	**201-18**	**Mean**
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	45.3	45.4	45.4	2.0	2.0	2.0	9.4	9.6	9.5
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	46.3	41.9	44.1	2.0	2.1	2.0	9.5	9.5	9.5
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	44.0	44.4	44.2	2.1	2.2	2.1	9.7	9.6	9.6
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	43.6	47.8	45.7	2.6	2.1	2.3	9.9	9.7	9.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	41.8	43.1	42.4	2.2	2.2	2.2	9.8	9.7	9.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	43.4	43.3	43.3	2.1	2.1	2.1	9.6	9.6	9.6
T_7	Pyroxsulam 4.5% with surfactant	18.75	48.0	44.5	46.2	2.3	2.1	2.2	9.9	9.7	9.8
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	44.1	43.2	43.7	2.5	2.1	2.3	9.5	9.6	9.6
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	44.0	45.1	44.5	2.0	2.0	2.0	9.7	9.7	9.7
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	45.8	45.7	45.7	1.6	2.0	1.8	9.3	9.6	9.4
T_{11}	Hand weeding twice	30 & 60 DAS	41.8	41.8	41.8	2.1	2.1	2.1	9.8	9.8	9.8
T_{12}	Control (weedy check)	-	44.0	44.1	44.0	2.6	2.2	2.4	9.6	9.4	9.5
SEm ±			1.27	1.64	1.46	0.23	0.11	0.17	0.16	0.12	0.14
CD (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS

*Figures in parenthesis are original values

Appendix XXXVIII. Effect of different herbicidal treatments on biological, seed and stover yield (kg ha^{-1}) succeeding soybean crop

Treatment		Dose (g *a.i.*ha^{-1})	Biological Yield (kg ha^{-1})			Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
			2016-17	2017-18	mean	2016-17	2017-18	Mean	2016-17	201-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	14.38	5582	5511	5546	1887	1773	1830	3695	3738	3717
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	19.17	5531	5468	5500	1842	1779	1811	3689	3689	3689
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant	23.96	5800	5813	5806	1814	1827	1821	3985	3985	3985
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	14.38	5785	5684	5735	1911	1811	1861	3874	3874	3874
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	19.17	5556	5556	5556	1730	1730	1730	3826	3826	3826
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant	23.96	5468	5435	5451	1860	1828	1844	3607	3607	3607
T_7	Pyroxsulam 4.5% with surfactant	18.75	5596	5596	5596	1878	1878	1878	3719	3719	3719
T_8	Halauxifen-methyl 10.42% with surfactant	5.21	5786	5574	5680	1970	1808	1889	3815	3766	3791
T_9	Sulfosulfuron + Metsulfuron – methyl 80 with surfactant	32	5727	5770	5749	1843	1921	1882	3884	3849	3867
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% with surfactant	47.93	5360	5322	5341	1879	1841	1860	3481	3481	3481
T_{11}	Hand weeding twice	30 & 60 DAS	5751	5751	5751	1878	1878	1878	3874	3874	3874
T_{12}	Control (weedy check)	-	5706	5641	5674	1880	1815	1848	3826	3826	3826
SEm ±			190.86	171.22	181.04	59.89	58.59	59.24	150.76	138.15	144.46
CD (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS

*Figures in parenthesis are original values

Appendix XXXIX. Analysis of variance for density of different weed at 30 DAA during *Rabi* season 2016- 17 and 2017-18.

Source of variation	D.F.	MSS											
		Weed density (m^{-2})											
		Cyperus iria		*Cichorium. intybus*		*Medicago denticulata*		*Anagallis arvensis*		*Chenopodium album*		*Medicago trancaltula*	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Replication	2	0.484	0.185	0.886	0.601	0.407	0.014	0.256	0.112	0.049	0.124	0.728	0.285
Treatment	11	26.051	27.084	25.444	25.952	97.408	92.45	27.881	31.329	35.045	39.686	59.808	58.581
Error	22	1.550	2.019	1.806	2.719	3.031	3.284	0.642	1.634	1.302	1.973	1.187	1.584

Appendix XL. Analysis of variance for dry weight of different weed at 30 DAA during *Rabi* season 2016- 17 and 2017-18.

Source of variation	D.F.	MSS											
		Weed dry weight (g m^{-2})											
		Cyperus iria		*Cichorium. intybus*		*Medicago denticulata*		*Anagallis arvensis*		*Chenopodium album*		*Medicago trancatula*	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Replication	2	1.398	0.859	0.283	0.206	0.119	0.008	0.057	0.038	0.017	0.087	0.407	0.158
Treatment	11	6.799	6.821	12.321	19.524	41.947	37.628	8.787	27.297	15.993	37.057	42.642	40.802
Error	22	0.483	0.427	0.551	1.004	0.884	1.024	0.137	0.618	0.388	1.012	0.632	0.841

Appendix XLI. Analysis of variance for plant population and plant height of wheat during *Rabi* 2016-17 and 2017-18

Source of variation	D.F.	MSS											
		Plant population				Plant height							
		Initial		Harvest		At 30 DAS		At 60 DAS		At 90 DAS		At harvest	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Replication	2	560.167	610.167	554.056	1.056	0.028	20.181	90.997	84.41	24.283	14.328	3.529	10.122
Treatment	11	138.083	155.333	270.972	12.306	22.938	79.942	297.715	288.956	260.255	328.478	214.487	338.51
Error	22	252.5	444.5	519.278	10.944	28.77	38.706	60.581	66.441	33.258	89.746	32.373	8.391

Appendix VLII. Analysis of variance for number of tillers and Leaf area index of wheat during *Rabi* 2016-17 and 2017- 18

Source of variation	D.F.	MSS											
		Number of tillers meter row length						Leaf area index					
		At 30 DAS		At 60 DAS		At 90 DAS		At 30 DAS		At 60 DAS		At 90 DAS	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Replication	2	131.556	285.056	56.722	69.5	661.556	499.5	0.006	0	0.054	0.004	0.241	0.003
Treatment	11	200.972	462.306	2,072.22	2,124.67	2,788.31	2,514.75	0.048	0.035	1.196	1.11	2.496	2.555
Error	22	181.111	684.944	63.278	73.833	191.111	268.5	0.246	0.209	0.04	0.036	0.202	0.045

Appendix XLIII. Analysis of variance for chlorophyll content and crop biomass of wheat during *Rabi* 2016-17 and 2017-18

Source of variation	D.F.	MSS											
		Chlorophyll content (%)						Crop biomass (g m^{-2})					
		At 30 DAS		At 60 DAS		At 90 DAS		At 30 DAS		At 60 DAS		At 90 DAS	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Replication	2	1.12	0.383	1.119	2.264	0.412	0.265	54.056	98.667	1,666.2	15,630.22	166.5	16,242.67
Treatment	11	1.664	2.234	93.073	138.099	20.877	2.507	158.222	591.333	109,869.0	93,034.22	108,664.3	86,145.33
Error	22	4.955	2.131	7.919	27.374	4.759	3.62	239.278	1,090.00	5,671.8	10,575.78	21,886.17	39,158.00

Appendix XLIV. Analysis of variance for crop growth rate and relative growth rate of wheat during *Rabi* 2016-17 and 2017-18

Source of variation	D.F.	MSS			
		Crop growth rate (g m^{-2} day^{-1})			
		30-60 DAS		60-90 DAS	
		2016-17	2017-18	2016-17	2017-18
Replication	2	0.917	1.261	0.708	2.634
Treatment	11	74.893	82.874	33.926	27.742
Error	22	4.115	4.683	3.459	5.162

Appendix XLV. Analysis of variance for crop growth rate and relative growth rate of wheat during *Rabi* 2016-17 and 2017-18

Source of variation	D.F.	MSS											
		Yield attributes								Yields			
		Effective tillers (meter^{-1} row length)		**ear head length (cm)**		**Grains ear^{-1}**		**Test weight (g)**		**Grain yield (kg ha^{-1})**		**Straw yield (kg ha^{-1})**	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	207-18	2016-17	2017-18	2016-17	2017-18
Replication	2	882.389	609.056	0.538	0.493	0.641	9.795	0.411	0.427	26,724.06	52,008.8	14,028.39	8,441.06
Treatment	11	6,514.22	6,803.64	7.635	7.301	40.368	203.118	29.169	22.306	7,238,273.9	5,750,434.8	8,770,370.89	4,945,101.64
Error	22	750.278	984.944	0.337	0.51	0.967	12.913	4.256	4.516	77,103.94	85,391.2	94,459.61	70,571.61

Appendix XLVI. Analysis of variance for NPK uptake by wheat during *Rabi* 2016-17 and 2017-18

Source of variation	D.F.	MSS											
		Nutrient uptake (kg ha^{-1})											
		By grain						By straw					
		N		P		K		N		P		K	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Replication	2	11.136	8.53	1.056	0.69	0.012	0.815	0.634	0.158	0.644	0.915	2.302	3.716
Treatment	11	3,974.81	2,637.17	228.306	124.673	267.801	216.982	314.635	199.779	66.127	52.019	2,069.24	1,312.17
Error	22	55.539	19.111	8.944	6.454	7.286	5.942	9.505	5.258	10.597	10.801	236.854	244.516

Appendix XLVII. Analysis of variance for harvest index and weed index of wheat during *Rabi* 2016-17 and 2017-18

Source of variation	D.F.	MSS			
		Harvest index (%)		Weed index (%)	
		2016-17	2017-18	2016-17	2017-18
Replication	2	1.725	1.204	7.272	12.921
Treatment	11	26.911	47.187	2,947.08	2,415.08
Error	22	6.111	3.589	33.435	37.919