“Studies on mitigation of drought effect through foliar spray of chemicals on soybean (Glycine max L. Merril) under rainfed condition.”

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya,

Jabalpur

In partial fulfillment of the requirement
For the Degree of

MASTER OF SCIENCE

In

AGRICULTURE

(AGRONOMY)

By

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Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur,

Madhya Pradesh

2016

CERTIFICATE- I

This is to certify that the thesis entitled, **"Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition"** submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE in AGRICULTURE** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Jitendra Marskole** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged by him.

Place- Rewa

Date- **(Dr. V.D. Dwivedi)**

Chairman of the Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	(Dr. V.D. Dwivedi)	…….
Member	(Dr. D.P. Dubey)	…….
Member	(Dr. I.M. Khan)	……..
Member	(Dr. R.K. Tiwari)	……..

CERTIFICATE- II

This is to certify that the thesis entitled **"Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition"** submitted by **Mr. Jitendra Marskole** to Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURE** in the **Department of Agronomy,** College of Agriculture, Rewa (M.P.) has after evaluation been approved by the Student's Advisory Committee after an oral examination of the same.

Place- Rewa

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Director of Instructions ……

Declaration and undertaking by the candidate

I, *Mr.* Jitendra Marskole S/o Shri Suraj Prasad Marskole certify the work embodied in thesis **"Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition"** is my own first hand bonafide work carried out by me under the guidance of Dr. V.D. Dwivedi. Scientist of the Department of Agronomy, College of Agriculture, Rewa (M.P.) during 2015-16.

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 acts of misinterpretation, mistakes, error 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: Rewa

Date: Signature of the student

Mr. Jitendra Marskole

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Name of the candidate – ***Mr.*** **Jitendra Marskole**

Subject – Agronomy

Department - Department of Agronomy

College - College of Agriculture, Rewa (M.P.)

Year of thesis submission - 2015-16

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The undersigned **Mr. Jitendra Marskole** assigns to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur Madhya Pradesh, all rights under Copyright Act that may exists in and for the thesis entitled- **"Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition"** submitted for the award of M.Sc. (Ag.) Agronomy.

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Name and Signature

Signature of the student
Mr. Jitendra Marskole

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It is a great movement for me so i am heartly thankful to God for giving me blessing and always illuminating me with the light of success. It is a movement of great pleasure to put in record my heartfelt gratitude and indebtedness to honourable guide and chairman of my Advisory Committee **Dr. V.D. Dwivedi**, Scientist of Agronomy, College of Agriculture, Rewa (M.P.), for his able magnificent guidance, inspirations, constructive criticisms and encouragements during the course of investigation and preparation of the thesis**.**

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College of Agriculture, Rewa (M.P.) (Jitendra Marskole)
Date ---------

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List of Abbreviations

Words	Abbreviations/ Symbols
At the rate of	@
Centimetre	cm
Co-workers	*et al*
Critical difference	C. D.
Days after sowing	DAS
Degree centigrade	^{0}C
Degree of freedom	d.f.
Diammonium phosphate	DAP
Figure	Fig.
Fisher's value	"F"
Gram (s)	g
Gross monetary returns	GMR
Hectare	ha
Kilogram(s)	kg
Land Equivalent Ratio	LER
Mean sum of square	MSS
Metre	m
Nitrogen	N
Non-significant	N.S.
Number	No.
Net monetary returns	NMR
per hectare	ha^{-1}
Per	/
Percent	%
Phosphorus	P_2O_5
Potassium	K_2O

Potential of hydrogen ions	pH
Quintal	q
Quintal per hectare	qha^{-1}
Replication	R
Rupees	Rs.
Serial No.	S. No.
Square metre	m^2
Square centimetre	cm^2
Significant at 5% level	*
Source of variation	S. V.
Standard error of means	S. Em $\pm$
Standard evaluation system	SES
Standard error of difference	S.Ed
Sum of square	S.S.
Square	sq.
That is	i.e.

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Diamond Higher Secondary School Satwas Dist- Dewas (M.P.)	**12th**	**M.P Board**	**2009**	**67.22%**

For the partial fulfillment of the master's degree programme he was allotted a field research experiment on**, "Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition."** Which was successfully conducted by him and being submitted in the form of this thesis.

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INTRODUCTION

Soybean (*Glycine max* L. Merril**)** is one of the commercial crops in India. Soybean is a crop of multiple qualities, as it is both a pulse and oilseed crop. It contains 40 percent protein and 20 percent edible oil, besides minerals and vitamins. As per survey conducted by SOPA, the all India estimated production 12.98 million tonnes from an area of 12.03 million hectare with productivity of 1079 kg/ha. In Madhya Pradesh, the area under soybean cultivation is 6.26 million hectares with the production of 5.95 million tonnes**.** Although the ecological conditions of the state are congenial for soybean production, but the yield is substantially low (950 kg/ha), despite of the best management practices (SOPA, 2014).

Its protein has great potential as a major source of dietary protein. The oil produced from soybean is highly digestible and contains no cholesterol. Growth, development and yield of soybean are the result of genetic potential interacting with environment.

Potassium (K) acts as a very essential and important nutrient for the plant growth and development. It is necessary in plants to improve the efficiency of photosynthesis and use of water. In soybean, deficiency of K causes so many problems and shows many deficiency symptoms in plants growth such as weaker straw, increased lodging and decrease in growth. Application of K to soybean plants under saline conditions enhances the growth of the plants and decreases the effect of salinity.

The effects of seed treatment (500 ppm) or foliar application of 1000 ppm thiourea (at 25 and 40 days after sowing) or a combination of these have been found effective on growth, yield, net photosynthesis and nitrogen metabolism of soybean (*Glycine max* L.**)** grown under rainfed conditions of the Indian arid zone. Thiourea application either as pre-sowing seed treatment or as foliar spray significantly increased plant height, leaf area, dry matter production and seed yield as compared to the untreated plants (Garg et al. 2006). However, maximum favourable effects were obtained with combined application of seed

treatment and foliar spray. The beneficial effects of thiourea were attributed to its role in significantly increasing the net photosynthetic rates and the concentrations of total chlorophyll and starch in the leaves. Thiourea also reflected a positive role in enhancing nitrogen metabolism as it significantly increased nitrate reductase activity and concentration of soluble protein in the treated plants. It has been found that seed treatment with thiourea followed by foliar spray could significantly improve growth, yield and water use efficiency of rainfed soybean under arid conditions due to enhanced photosynthesis and more efficient nitrogen metabolism (Garg et al. 2006). Foliar application of thiourea, KNO_3, KCl, along with insecticide have not been studied in soybean under rainfed condition of Rewa region.

Keeping above facts in view, present study has been taken with following objectives:-

Objectives of Investigation:

1. To assess the growth and development of soybean as influence by different chemicals spray.
2. To find out the suitable chemical to mitigate drought in soybean.
3. To judge the comparative performance of different chemicals and water spray from control on the basis of economics of treatments.

REVIEW OF LITERATURE

Hopper et al. (1979) indicated that in primed seeds because of more water uptake efficiency and faster metabolic activity in term of germination, radicle and plumule appeared faster. The similar results were reported by other researchers. Except of cultivar × salinity stress and cultivar × prime × salinity stress interaction on leaf area per plant, other simple and interaction effects were significant.

Sathiyamoorthy and Vivekanandana (1988) observed that pre-sowing seed treatment with KNO_3, $NaNO_3$, NaCl, thiourea and di-Ammonium phosphate (DAP) resulted in better development of the root and shoot system than the control. As a result of pre sowing seed treatment, there was an increase in dry matter production by 44, 27 and 32% over the control in KNO_3, $NaNO_3$ and DAP treatments respectively. Similarly increase in seed yield was noticed in $NaNO_3$ (45%), KNO_3 (40%) and DAP (50%) pre treated plants.

Sathiyamoorthy and Vivekanandana (1988) studied the cumulative effects of foliar spray on plants raised from pre-sowing seed treatment, salt solutions (NaCl, KNO_3, $NaNO_3$, thiourea, DAP) at optimal level sprayed separately three times at three different stages of development. As a result of foliar spray moderate increase in growth in KNO_3 (20%), thiourea (29%) and DAP (25%) treatment was observed over the control. Seed yield increased significantly (56-70%) in all treatments except NaCl spray, due to increase in the number of pods(41-63%) $plant^{-1}$. Foliar spray of nutrients increased protein yield without affecting the oil content.

Sarkar and Mukhopadhyay (1990) reported that foliar spray of 0.5 per cent KNO_3 solution at 50 per cent flowering stage significantly increased the grain yield of high yielding and traditional cultivars by 49.1 and 19.3 per cent, respectively over control in rice.

Singh and Rao (1993) reported that in stress condition, potassium nitrate effectively improved germination, seedling growth and seedling vigour index of the seeds of sunflower (*Helianthus annuus*) varieties with low germination.

Shindhe and Jadhav (1995) observed that foliar spray of growth regulators (NAA and ethrel) and KNO_3 in cowpea increased the pod yield plant^{-1}, weight of individual pod and ultimately resulted in elevating the seed yield by 33 per cent.

Bly et al. (1996) revealed that the experiment did not show any differences in the amount of leaf canopy burn between the two sources of K, but did show that increased rates of applied foliar K significantly reduced grain yield.

Samoylov et al. (1998) evaluated the effect of K^+ content on proliferation of cultures, the amount of KNO_3 was lowered from 27.9 mM to 20.7 mM, and 3.5 mM (NH.)2S0" were replaced with 7.0 mM NH.NO". Therefore, this formulation contained the same amount of total nitrogen, aromonium, and nitrate as FNN6 basal medium, although the amount of K^+ was lowered from 29.4 to 22.3 mM, which corresponds to 76.1% of K^+ in FNN6. Thereafter, 3.3, 7.0, 10.7, and 14.3 mM of KCl were added to obtain media with 25.7, 29.4, 33.0, and 36.7 mM of K^+, which correspond to 87.5, 100, 112.5, and 125.0% of the K^+ level in FNN6 basal medium, respectively.

Kattimani et al. (1999) indicated that primed seeds with nitrate solutions produced vigorous seedlings, more dry matter accumulation and root length in compared with non-primed seeds.

Govindan and Thirumurugan (2000) observed that the foliar spray of KCl (one per cent) + KNO_3 (one per cent) increased the grain yield of greengram by 21.8 per cent.

Govindan and Thirumurugan (2000) reported that the growth parameters *viz.,* LAI in green gram were significantly higher with the foliar spray of KNO_3 (one per cent) or KCl (one per cent) and their combination.

Nikolova *et al*. (2000) on their studies on soybean reported that alteration in N, S and K levels was effective on electrophoretic patterns of seed proteins.

Harris et al. (2001) reported that seed priming led to better establishment and growth, earlier flowering and greater yield.

Sarkar and Malik (2001) reported that the foliar spray of KNO_3 and $Ca(NO_3)_2$ salts exerted conspicuous effects on yield attributing characters of grasspea. Foliar spray of KNO_3 at 0.50% during 50% flowering stage showed maximum values of pods/plant, length of pod, seeds pod^{-1} and 1000 seed weight; it was significantly superior to water spray and unsprayed control, but was on par with $Ca(NO_3)_2$ at 0.406%.

Sarkar and Malik (2001) reported that the foliar spray of KNO_3 at 0.50% when sprayed during 50% flowering stage while equivalent to $Ca(NO_3)_2$ at 0.406%, recorded a significantly and appreciably higher seed yield than spray of KNO_3 at 0.25 and 1.00%, $Ca(NO_3)_2$ at 0.203 and 0.812%, water spray and unsprayed controls. This was the case in both years and also in the pooled data. The increase in seed yield due to spraying of KNO_3 at 0.50% at 50% flowering stage was 78.4 and 85.7% over the water sprayed and controls, respectively.

Ramesh and Thirumurugan (2001) stated that foliar applications of 2 percent DAP and 1 percent KCl along with benzyladenine 25 ppm had significantly increased the plant height in soybean.

Imsande (2001) found that the protein synthesis in soybean was influenced by elements such as P, K, N and the optimum application of these elements increased storage proteins.

Almansouri et al.(2001) expressed that salinity stress is an important factor in preventing or delaying seed germination and seedling establishment. Some researchers have reported negative effects of salinity stress on seed germination and crop production.

Bernardi ACC (2002) results showed that VRT of potassium for this plot could be performed based on yield maps, and it could be used in reducing yield variability and maintaining profitability while optimizing K applications.

Gordon et al. (2002) studies on the soybean plants exposed to 10 mm KNO_3 for a 4 days period were used to test the correlation between nitrogenase activity, gene expression and sucrose metabolism. Nitrate caused the down-regulation of sucrose synthase transcripts within 1 days, although a decline in nodule sucrose synthase activity and an increase in nodule sucrose content only occurred after 3-4 days.

Ebert et al. (2002) found that supplying of Ca $(NO_3)_2$ at 10 mm had a beneficial effect on growth and metabolism of NaCl treated guava seedlings.

Reddy et al. (2004) recorded that the effect of potassium nitrate and NAA on growth and yield of red. The foliar application of NAA 20 ppm + KNO_3 0.5 percent significantly increased the dry matter production, seed yield.

Hu and Schmidhalter (2006) repoted that the potassium increases enzyme activity (antioxidant enzymes) and neutralizes negative effects of free radicals by influencing antioxidant enzymes .

Kaya et al. (2006) indicated that priming of sunflower seeds with KNO_3 led to increasing of germination percentage in drought and salinity stresses. Several studies confirmed positive effects of seed priming on germination.

Ebadi et al. (2006) resulted that the application of nitrogen led to a reduction in the adverse effect of water deficit, with increase in the application to as much as 90 kg pure nitrogen per hectare resulting in a significant increase in the yield of soybeans as evidenced through the increase in the number of pods $plant^{-1}$ as well as the grain weight of soybeans in all levels of irrigation condition. Corresponding to an increase in the amount of nitrogen applied from 30 to 90 kg per hectare, increases yield of 53%, 84% and 54%, respectively in 7, 14 and 21 days irrigation intervals.

Guzman and Olave (2006) reported that seed priming with nitrate solutions led to improved germination rate and germination index.

Bocian and Ubowicz (2008) showed that seed priming with KNO_3 for 6 and 12 hours, improved seed germination of tomato and reduced mean

germination time. In other studies the positive effects of priming on seed germination has been confirmed. Increasing of salinity stress led to significant, reduction in FGP in both non-primed and primed seeds. Minimum value of this trait was obtained at levels of 8 dSm and non-priming, so that at the mentioned salinity level, germination of primed seeds with KNO_3 was 21.5 percent more than non-primed seeds.

Mohammadi (2009) found that among the priming treatments, primed seeds with potassium nitrate showed the highest values for all traits and priming with KNO_3 than control, increased germination percentage, germination rate and seedling dry weight by 28.3, 129.4 and 58.1 percentage, respectively.

Hatami et al. (2009) cultivar and N fertilizer significantly effected on seed yield with increasing of N fertilizer application, seed yield increased significantly.

Akram et al. (2009) observed an improvement in growth of sunflower due to the foliar spray of K_2SO_4 and KNO_3 at 1.25% under saline concentration of 150 mm NaCl.

Lin et al. (2010) reported that the fruit body yields and biological efficiency recorded were all highest in cultures of soybean crop supplemented with sucrose and KNO_3 as carbon and nitrogen supplements, respectively. Highest fruit body yields and biological efficiency values were recorded with C:N ratio of 12:1. The optimal medium consisted of soybean powder, beef extract and KNO_3. Cultivation experiments using this medium confirmed its reliability; 35% of biological efficiency was obtained, compared with a calculated maximum biological efficiency of 65% based on orthogonal test data.

Nelson et al. (2010) to evaluate the effect of pre plant and foliar-applied KCl on soybean response. Leaf Cl concentrations increased significantly with pre plant KCl at Qulin and foliar KCl. Pre plant KCl, increased yield 340 kg ha^{-1}, while foliar KCl increased yield 110 kg ha^{-1}.

Afkari (2010) found that seedlings dry weight of primed seeds were more than non-primed seeds at the all salinity levels.

Muhammad et al. (2014) reported that the single application of KNO_3 greatly enhanced bioactive GA_1 and GA_4. Soybean thus showing a differential response in bioactive gibberellin metabolism to KNO_3 nutrition. Our results also demonstrated that application of KNO_3 was more effective at lower salt stress level as GA_1 and GA_4 contents in soybean leaves were higher with basic NaCl (70 mm) as compared to double NaCl (140 mm) treated plants.

Muhammad et al. (2014) reported that the KNO_3 application enhanced shoot length, fresh and dry shoot weight, fresh and dry root weight as compared to control treatment so its application alleviated the detrimental effect of NaCl on soybean growth parameters. Foliar supply of KNO_3 to the salt treated plants may reduce toxic ions uptake as well improve K and N status of salt treated plants. Potassium has role in ionic balance which is reflected in nitrate metabolism.

Muhammad et al. (2014) reported that the nitrogen plays role of chlorophyll and protein so act as an essential element for plant growth. Potassium application result an increase in leaf potassium content which was accompanied by increased rates of photosynthesis, photorespiration and RuBP carboxylase activity.

Rahul and Parhe (2015) reported that the treatments (T_4) 100 ppm GA_3 12 hr (2078.00g $plot^{-1}$), (T_8) hydration with IAA 80 ppm 12 hr (2008.67g $plot^{-1}$), (T_5) hydration with 0.5 per cent KNO_3 12 hr (1991.00g $plant^{-1}$) seed yield $plot^{-1}$ respectively over the untreated control T_1 (1647.67g $plot^{-1}$) showing to the corresponding favourable improvement in number of pods $plant^{-1}$, number of seeds pod^{-1}, test weight (g), seed yield $plot^{-1}$ (g), seed yield Ha^{-1} (q), biological yield (g) and numerical harvest index (%).

Rahul and Parhe (2015) reported that all the treatments the treatments (T_4) 100 ppm GA_3 12 hr (2078.00g $plot^{-1}$), (T_8) hydration with IAA 80 ppm 12 hr (2008.67g $plot^{-1}$), (T_5) hydration with 0.5 per cent KNO_3 12 hr (1991.00g $plant^{-1}$) produced significantly more test weight than control. In respect of seed yield plot all the seed priming treatments were significantly produced more seed yield $plot^{-1}$ than control, T_1 (1647.67g plo^{t-1}). The treatments T_4 (hydration with 100 ppm GA_3 12 hour) (2078.00g $plot^{-1}$), T_8 (hydration with IAA-80 ppm 12hr) (2008.67g

plot^{-1}), T_5 (hydration with 0.5 per cent KNO_3 for 12 hr) (1991.00g plot^{-1}) and T_7 (Hydration with water 12 hr + Bavistin @ 3.0g kg^{-1} of seed) (1984.00g plot^{-1}) recorded higher seed yield than control.

Rahul and Parhe (2015) found that the treatment the treatments (T_4) 100 ppm GA_3 12 hr (2078.00g plot^{-1}), (T_8) hydration with IAA 80 ppm 12 hr (2008.67 g plot^{-1}), (T_5) hydration with 0.5 per cent KNO_3 12 hr (1991.00g plant^{-1}) plant stand at harvest is also found significant among the different treatments. Treatments T_4 (77.19), T_8 (76.55), T_3 (76.22) recorded higher plant population at harvest. All the seed priming treatments maintained more plant populations than untreated control T_1 (72.74), which was ultimately reflected in good seed yield at harvest.

Rahul and Parhe (2015) reported that the treatment the treatments (T_4) 100 ppm GA_3 12 hr (2078.00g plot^{-1}), (T_8) hydration with IAA 80 ppm 12 hr (2008.67g plot^{-1}), (T_5) hydration with 0.5 per cent KNO_3 12 hr (1991.00g plant^{-1})the improvement in the seed yield one has to consider the biological yield plant^{-1}. The treatments T_4 (5084.77), T_7 (5058.27) and T_8 (4944.97) were recorded significantly higher biological yield (g) than control T_1 (4508.67g p plot^{-1}). Harvest index (%) also noticed significantly more in T_4 (40.88%), numerically more in T_8 (40.63%) as compare to other treatments. The lowest H.I. (%) was noted by treatment T_1 (36.61%). Harvest index (H.I.) is the ratio of partitioning of biological yield into economic yield.

Parmoon et al. (2015) reported that the potassium nitrate leads to the increase of potassium in cells of soybean.

MATERIALS AND METHODS

The present investigation was planned and taken up within the scope of the subject under study and the objective framed out to realise the answers for the problem identified, as depicted in the chapter of introduction, during the *kharif* season of 2015 under edaphic and climatic conditions of Rewa (M.P.). The materials used and the methods employed during the course of investigation in the field as well as laboratory are briefly described in this chapter under the appropriate heads.

3.1 Experimental site

A field experiment was conducted at AICRP for Dryland Agriculture, Kuthulia Farm College of Agriculture, Rewa (M.P.) The field selected for experimentation was fairly infested with location specific foliar spray representing to this area having uniform topography. All physical facilities *viz*., labour, agrochemicals, equipments and inputs etc. were adequately available as per needs on the research farm.

3.2 Climate and weather conditions

Rewa is situated in the North- Eastern part of Madhya Pradesh at $24^0$31' North latitude, $80^0$19' East longitude and 365.7 metre above mean sea level, it has sub-tropical climate. Hot and dry summer and cold –winter are the main characteristic features of this region. The minimum and maximum temperature occasionally reaches 8^0C and 44^0C respectively.

Summer months are hot and May is the hottest month when temperature reaches upto 44^0C. Winter months experience mild- cold with the lowest temperature touching 4^0C during December- January.

The annual rainfall of this tract ranges from 900 to 1200 mm which mostly occurs during July to September. The onset of monsoon is mostly expected by the end of June to beginning of July and cessation by September, most of the rainfall received during July and August months. The sunshine hours and other meteorological factors remained favourable for the growth of soybean. The monthly rainfall, number of rainy days, temperature,

humidity and bright sunshine hours for the entire crop season (June to October are presented in Table 3.1 and exhibited through Fig 1.

The perusal of data reveals that the total rainfall received during the crop growth season (June to October, 2015) was 689.2 mm. The mean lowest temperature 11.27 ^{0}C was recorded in the month of October, whereas the maximum temperature 44.14^{0}C was noted in month of June. Relative humidity was the highest 86.71 % in the month of August.

Table 3.1: Standard Weekly Meteorological data during crop season of 2015

SWM	Temperature (^{o}C)		RH (%)		Rainfall (mm)	No. of rainy days
	Maximum	Minimum	Maximum	Minimum		
22	44.14	25.95	31.85	16.57	-	-
23	42.51	27.07	34.57	18.28	-	-
24	39.07	25.77	51.14	27.42	9.4	1
25	38.88	27.07	52.71	22.14	-	-
26	34.28	23.08	76.14	42.71	87.20	4
27	34.74	23.45	71.42	66.85	108.00	6
28	32.27	24.04	83.42	71.00	73.40	5
29	32.81	24.21	85.85	69.14	58.80	4
30	32.00	23.52	76.28	71.28	14.00	1
31	32.28	23.40	77.28	62.71	47.40	3
32	33.22	23.34	81.14	60.85	81.4	2
33	32.87	24.21	81.14	67.71	116.00	5
34	32.37	23.65	77.84	64.71	6.60	1
35	32.78	23.85	86.71	65.28	15.4	2
36	34.51	23.42	78.14	56.14	-	-
37	34.97	22.48	75.00	57.00	-	-
38	34.62	24.15	74.85	60.14	6.00	1
39	34.78	20.14	68.28	41.28	-	-
40	35.97	18.81	65.28	45.28	-	-
41	35.77	17.98	58.71	39.71	-	-
42	34.85	18.30	60.71	34.14	-	-
43	34.87	17.01	70.42	58.14	-	-
44	28.71	15.74	82.14	52.50	81.00	2
45	31.30	16.80	77.85	56.28	-	-
46	31.14	13.35	71.28	41.85	-	-
47	29.51	11.27	7.343	47.85	-	-
48	31.20	14.11	75.00	49.28	-	-
Total					689.2	37

Source: Meteorological Observatory, Kuthulia Farm, Rewa (M.P.)

3.3 Soil

The soil of the Rewa region is broadly classified as vertisol as per norms of US classification of soil. It has medium to deep in depth and medium black in colour. It swells by wetting and shrinks when dries. Thus, it develops wide cracks on the surface during summer season.

To evaluate the physico-chemical properties of the soil, the ten soil sample were taken randomaly from the experimental field with the help of screw type soil auger from different places to a depth of 15 cm. These soil samples were thoroughly mixed together to get a composite sample. After proper drying, the samples were powdered finely with the help of pistal and mortar and later a composite sample was drawn by quartering. Then this composite soil sample was subjected to various analysis in the laboratory, Department of Agronomy, JNKVV, College of Agriculture, Rewa. The analytical values are given in the Table 3.2.

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

Constituents	Value	Class/ groups	Method used
A. Mechanical composition			
Sand (%) Silt (%) Clay (%)	25.15 19.18 55.67	Clayey	International pipette method (Piper, 1967)
B. Chemical analysis			
Organic carbon (%)	0.60	Medium	Walkey and Black rapid titration method (Walkey and Black,1934)
Available nitrogen (kg/ha)	350	Medium	Alkaline permanganate method (Subbiah and Asija,1956)
Available P_2O_5 (kg/ha)	16.50	Medium	Colorimetre method (Olsen et al. 1954)
Available K_2O (kg/ha)	333	High	Flame photometre method (Chapman and Pratt, 1961)
Soil pH (1:2.5 soil water ratio)	7.1	Neutral	Glass electric pH metre (Piper,1967)
Electrical Conductivity (ds/m)	0.33	Neutral	Solu-bridge method (Black, 1965)

It is obvious from the data given in Table 3.2 indicate that the percentage of clay is high followed by sand and silt, indicating clearly that soil of the experimental field was clayey in texture which is quite suitable for rairing any crop. The soil is neutral in reaction (7.1), medium in organic carbon (0.60%), available N (350 kg/ha), available P (16.50 kg P_2O_5 ha^{-1}) and high in available K (333 kg K_2O ha^{-1}).

The cropping history of the experimental field during last five years is given in the Table 3.3.

Table 3.3. Previous cropping history of the experimental field

Year	***Kharif***	**Rabi**
2010-2011	Soybean	Wheat
2011-2012	Soybean	Wheat
2012-2013	Soybean	Wheat
2013-2014	Soybean	Wheat
2014-2015	Experiment of soybean	Wheat

In the experimental field soybean-wheat cropping system was followed from 2010 to 2015 and both component crops were well supplied with recommended dose of fertilizer.

3.4 Preparation of the field

In order to get a good tilth for sowing of soybean in the present experimental field one summer ploughing followed by one pass of tractor driven cultivator and two pass of disc harrow and then the field was finally leveled by leveler, before seeding of the soybean crop in the experimental field.

3.5 Layout of the field experiment

The field experiment was laid out in Randomized Block Design with three replication. The eight treatments combination were randomized within each replication using random table. The layout plan of the treatments are graphically illustrated through the Figure 2. The details of the treatments are given below.

Details of the treatments

Treatments : 8 foliar spray measures

T_1 : Control

T_2 : Water spray at 25-30 and 55-60 DAS

T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS

T_4 : Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS

T_5 : Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS

T_6 : T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix

T_7 : T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix

T_8 : T_3+ Trizophos insecticide@600 ml ha^{-1} tank mix

Design : Randomized Block Design

Replications : 3

Other details of the experiment

Gross plot size	: 6.0 m x 4.80 m
Net plot size	: 5.50 m x 4.20 m
Distance between replications	: 1.0 m
Distance between plots	: 0.5 m
Distance between rows	: 30 cm
Total number of plots	: 24
Variety	: JS 20-29
Seed rate	: 75 kg/ha
Date of sowing	: 02-07-2015
Fertilizer application	: 20:40 kg N and P_2O_5 ha^{-1}
Date of harvesting	: 28-09-2015

3.6 Agronomic characters of crop variety

An early maturing (95 days, high yielding (25-30q ha^{-1}), multiple resistant (yellow mosaic virus, charcoal rot, blight, bacterial pustule, leaf

spots, stem fly, stem bores and defoliators) variety suitable for double cropping rainfed situation and intercropping. It possesses excellent germinability and longevity.

3.7 Schedule of agronomic operations

Schedule of agronomic operations done in the experimental field during the course of experimentation are given in Table 3.4 in chronological order.

Table 3.4. Details of different field operations done in soybean during kharif, 2015

S.No.	Field operation	Date	Remarks
1.	Land preparation	30-06-15	Mechanically
a.	Layout of the experiment	01-07-15	Manually
2.	Application of fertilizers	02-07-15	Manually
3.	Seed treatment and sowing of seed	02-07-15	Manually
4.	Application of herbicides as a post emergence	22-07-15	By Knapsack sprayer with flat fan nozzle
5.	Foliar spray of chemicals		
	a. First at 25-30 DAS	28-07-15	By Knapsack sprayer with flat fan nozzle
	b. Second at 55-60 DAS	29-08-15	By Knapsack sprayer with flat fan nozzle
6.	Harvesting	28-09-15	Manually by sickle
7.	Threshing and winnowing	05-10-15	Manually by hand
8.			

3.8 Fertilizer Application

Full dose of major plant nutrients (20 kg N + 40 kg P_2O_5 ha^{-1}) was applied as basal application through urea and single super phosphate. The whole quantities of all the fertilizers were applied manually at the time of sowing in the furrows about 3 cm below the seed.

3.9 Sowing Management

3.9.1 Seed treatment

Before sowing, the seeds were treated with carbendazim @ 1.0 g/kg of seed followed by inoculation with *Rhizobium* culture @ 5g kg^{-1} of seed.

3.9.2 Sowing time and sowing method

Sowing of seed was done manually on July 02, 2015. The rows were opened with the help of pick axe and later sowing was regulated for each plot using a seed rate of 75 kg ha^{-1}. Sowing of seeds in each plots was done in rows 30 cm apart at the depth of 3-4 cm and then seeds were covered with fine soil. There was light rainfall after sowing which helped in proper germination of seeds.

3.10 Weed Management

Foliar spray of Oddyssy @ 1 liter ha^{-1} was done as per treatment manually with the help of Knapsack sprayer with flat fan nozzle at 20 days after sowing as per plots.

3.11 Harvesting

The crop was harvested on September 28, 2015 when the foliage of the soybean plants turned yellowish brown to brown in colour and started to fall down. Harvesting was done by cutting one border row from each side and 25cm at both ends of the rows to eliminate the border effect. The harvested produce of each plot was removed from the field. After this, harvesting of crop from net plot area was done plot wise separately with the help of sickles manually. The harvested produce of each plot was tied into bundles and tagged with luggage label for demarcation. The plot wise produce was transported to threshing floor and allowed for sun drying for 7 days.

3.12 Threshing and Winnowing

After sun drying of produce of each plot on threshing floor, the produce was weighed plot wise by using spring balance. After this, threshing was done manually by beating up the produce with stick for each plot separately on October 05, 2015. The threshed material of each plot was containing seeds and chaffy materials. The chaffy materials were removed and clean seed of each plot was separated by winnowing with hand fan (*supa*) manually. The weight of clean seed obtained from each plot was recorded with the help of double pan balance.

3.13 Pre harvest studies

3.13.1 Plant population (Number m^{-2})

Initial and final plant population of crop was counted at 20 days after sowing (DAS) and just before harvesting, respectively from one metre running row length in 4 rows randomly in each plot and then averaged out. After this, plant population per metre square was determined from each plot.

3.13.2 Plant height (cm)

Five plants per plot were selected randomly in each plot and tagged for recording various observations. The height of marked plants was taken from the base (ground surface) to the tip of main stem with the help of metre scale. This observation was recorded at 20, 40, 60 DAS and at harvest each plot.

3.13.3 Number of branches $plant^{-1}$

The number of branches per plant was counted on the 5 tagged plants in each plot at 20, 40 and 60 DAS and then mean was determined for each treatment at all growth stages.

3.14 Post-harvest Observations

3.14.1 Number of pods $plant^{-1}$

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

3.14.2 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 pod^{-1}.

3.14.3 Seed index [100 seed weight (g)]

The hundred seeds were randomly taken from the finally cleaned produce of each plot for recording test weight. Then weight of 100 seeds of each plot was recorded separately on an electronic balance in the laboratory of Agronomy Department, Rewa.

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

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

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

The straw 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 straw yield per hectare by multiplying with the same conversion factor which was used in case of seed yield per hectare.

3.14.6 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:

$$\text{Harvest index} = \frac{\text{Economic yield (seed yield)}}{\text{Biological yield (seed and straw yields)}} \times 100$$

3.15 Economics of the Treatments

The economic analysis of the treatments is very important to asses the practical utility of treatments for farmers point of view. Therefore, economics of different treatments were worked out in terms of cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR) and benefit -cost ratio

(B:C) on per hectare area basis to ascertain the economic viability of the treatments. The detail for determination of economics are given in *Appendix* I for reference.

3.15.1 Cost of cultivation (Rs ha^{-1})

The cost of cultivation for each treatment is determined on the basis of different inputs used for raising the crop under different treatments on one hectare area basis.

3.15.2 Gross monetary returns (Rs ha^{-1})

The values realized from the produce obtained under each treatment was computed on the basis of existing market price of the produce (both seed and straw) as the gross monetary returns (GMR) per hectare under different treatments.

Gross monetary returns = value of seed + value of straw

3.15.3 Net monetary returns (Rs ha^{-1})

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

Net monetary returns = Gross monetary returns - Cost of cultivation

3.15.4 Benefit-cost ratio (B:C)

To estimate the benefit obtained under different treatments for each rupee of expenditure incurred, B:C ratio of each treatments was calculated as below :-

$$B{:}C\ Ratio = \frac{Gross\ monetary\ returns}{Cost\ of\ cultivation}$$

3.16 Statistical Analysis

The data obtained on various observations were tabulated and subjected to their analysis by using the techniques of the analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967) and the treatment

was tested by F test shown. Critical difference (C.D.) at 5% level of significance was determined for each characters to compare the differences among treatment means.

Table 3.5. The skeleton of analysis of variance

Source of variation	d.f.	SS	MSS	F. cal.	F.tab.
Replication (r-1)	3 –1 = 2				
Treatment (t-1)	8 – 1 = 7				
Error (r-1)(t-1)	2x7=14				
Total (rt-1)	rt –1 = 23				

$SEm\pm = \sqrt{EMS/r}$

$SEd = SEm. \times \sqrt{2}$

CD = SEd x t at 5% (14 d.f.)

RESULTS

The data pertaining to the growth and yield of the soybean crop are presented here with the help of appropriate tables and illustrations. The treatment wise data of each character were statistically computed as presented by analysis of variance (ANOVA) tables in the *Appendix* section. An attempt has also been made to calculate the economics of the various treatment combinations based on the existing market rates of the experimental inputs and out puts.

4.1 Studies on crops

4.1.1 Plant population (No. m^{-2})

Data recorded on plant population of soybean at 20 DAS and just before harvesting under different treatments are given in Table 4.1 and Figure 3.

Table 4.1: Influence of foliar spray of chemicals in soybean on average plant population for mitigating drought effect

Treatment	Plant population (No. m^{-2})	
	20 DAS	at harvest
T_1 : Control plot	37.33	35.00
T_2 : Water spray at 25-30 and 55-60 DAS	39.33	35.33
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	37.67	35.67
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	38.33	36.33
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	37.33	35.83
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	38.00	36.00
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	37.33	36.43
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	38.00	37.00
SEm±	**0.87**	**0.69**
CD (P=0.05)	**NS**	**NS**

The plant population of soybean was affected due to different foliar spray of chemicals and it was practically differ in all the foliar spray at 20 DAS and at harvest, including control plots where no foliar spray were applied,

suggesting that application of KNO_3, KCl and thiourea alone or its combination with trizophos at higher rates did not cause any adverse affect on crop plants. The plant population was non significantly under different treatments.

4.1.2 Plant height (cm)

Data on plant height recorded 20, 40, 60 DAS and at harvest stage under different foliar spray treatments are presented in Table 4.2 and Figure 4.

The plant height, in general was less under all the treatment during early period of crop growth, which was increased with age of crop and the maximum at 60 DAS and thereafter, it was slightly increase height of plant under all the treatments at harvest stage. However, the rate of increase in plant height was higher between 20 and 40 DAS.

At 20 DAS, the plant height was not affected significantly under different treatments. But, at 40 DAS remarkable variation in plant height was recorded under different foliar spray treatments. Plant height was minimum (45.66 cm) under control plots, which increased appreciably in plots receiving foliar spray treatments. Foliar spray of water at 25-30 DAS cause marginal increase in plant height (48.58 cm).The plant height (49.46 cm) increased identically when the foliar spray of 1% KNO_3 at 25-30 DAS. When the foliar spray at 55-60 DAS were slightly increase of plant height at all the stages. Maximum plant height was recorded plots receiving the combined application of 1% KNO_3 + Trizophos (@ 600 ml ha^{-1}) at 60 DAS (52.24 cm). Similar trends were also observed at harvest stage in relation to plant height of soybean.

Table 4.2: Influence of foliar spray of chemicals in soybean on average plant height for mitigating drought effect

Treatment	Plant height (cm)			
	20 DAS	40 DAS	60 DAS	at harvest
T_1 : Control plot	22.27	45.66	65.55	66.92
T_2 : Water spray at 25-30 and 55-60 DAS	23.70	48.58	69.64	71.00
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	24.13	49.46	70.94	72.31
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	23.80	48.78	69.97	71.34
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	23.63	48.43	69.42	70.79
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	25.07	51.37	73.68	75.05
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	24.30	49.79	71.32	72.68
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	25.50	52.24	74.83	76.20
SEm±	**0.56**	**0.87**	**1.12**	**1.44**
CD (P=0.05)	**1.73**	**2.68**	**3.47**	**4.47**

4.1.3 Number of leaves plant^{-1}

Data on branches of soybean plant at 20, 40 and 60 DAS stage under different foliar spray treatments are presented in Table 4.3 and Figure 5.

The number of leaves, in general was less under all the treatment during early period of crop growth, which was increased with age of crop and the maximum at 40 DAS and thereafter, it was slightly decrease number of leaves under all the treatments at harvest stage. However, the rate of increase in plant height was higher between 20 and 40 DAS.

At 20 DAS, the number of leaves was not affected significantly under different treatments. But, at 40 DAS remarkable variation in number of leaves was recorded under different foliar spray treatments. Number of leaves was minimum (16.01) under control plots, which increased appreciably in plots

receiving foliar spray treatments. Foliar spray of water at 25-30 DAS cause marginal increase in number of leaves plant^{-1} (16.87).

Table 4.3: Influence of foliar spray of chemicals in soybean on average number of leaves/plant for mitigating drought effect

Treatment	Number of leaves plant^{-1}		
	20 DAS	**40 DAS**	**60 DAS**
T_1 : Control	7.09	16.01	13.80
T_2 : Water spray at 25-30 and 55-60 DAS	7.42	16.87	14.67
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	7. 92	19.34	17.47
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	8.42	17.77	15.90
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	7.76	18.02	15.82
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	8.09	18.44	16.23
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	8.52	19.40	17.20
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	9.09	20.74	18.53
SEm±	**0.38**	**0.68**	**0.51**
CD (P=0.05)	**1.16**	**2.12**	**1.57**

The number of leaves (19.34) increased identically when the foliar spray of 1% KNO_3 at 25-30 DAS. When the foliar spray at 55-60 DAS were not effective number of leaves at all the stages. Maximum number of leaves was recorded plots receiving the combined foliar spray of 1% KNO_3 + Trizophos (@ 600 ml ha^{-1}) at 40 DAS (20.74 cm). Similar trends were also observed at 60 DAS in relation to number of leaves of soybean.

4.1.4 Number of branches plant^{-1}

Data on branches of soybean plant at 20, 40 and 60 DAS stage under different foliar spray treatments are presented in Table 4.4 and Figure 6.

The branches plant^{-1} in soybean were minimum at 20 DAS, which was increased with time and attained the maximum value at 60 DAS under all the treatments.

Table 4.4: Influence of foliar spray of chemicals in soybean on average number of branches plant^{-1} for mitigating drought effect

Treatment	Number of branches plant^{-1}		
	20 DAS	**40 DAS**	**60 DAS**
T_1 : Control	2.12	2.92	3.57
T_2 : Water spray at 25-30 and 55-60 DAS	2.26	3.06	3.70
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	2.39	3.43	4.08
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	2.64	3.19	3.84
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	2.43	3.23	3.85
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	2.50	3.30	3.95
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	2.64	3.44	4.10
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	2.85	3.65	4.31
SEm±	**0.12**	**0.13**	**0.13**
CD (P=0.05)	**0.39**	**0.40**	**0.41**

Different foliar spray caused significant variation on the number of branches plant^{-1} at 40 days after sowing. Control plots had the minimum number of branches per plant (2.92) which increased appreciably in plots receiving foliar spray. The foliar spray of water at 25-30 DAS and 55-60 DAS, 1% KCl solution at 25-30 DAS and thiourea@250g ha^{-1} solution at 25-30 DAS and 55-60 DAS cause marginal increase in branches plant^{-1} in soybean being the higher when these were applied at higher foliar spray of 1% KNO_3 at 25-30 DAS and 55-60 DAS respectively. The foliar spray of 1% KNO_3 at 25-30 DAS and 55-60 DAS produced more branches as compared to combined foliar spray

of thiourea@250g ha^{-1} + Trizophos solution at 25-30 DAS and 55-60 DAS spray. However, maximum branches recorded on the plots receiving the combined foliar spray of 1% KNO_3 + Trizophos (@ 600 ml ha^{-1}) at 40 DAS (3.65) of branches per plant and at par, nearly similar results were observed at 60 DAS stage.

4.1.5 Days to 50% flowering and days taken to maturity

Data on days to 50% flowering under different foliar spray treatments are presented in Table 4.5 and Figure 7.

4.1.5.1 50 percent flowering

It is clear from result that 50 percent flowering of soybean was differed significantly in control plots and different foliar spray chemicals and their combinations of soybean crops. 50 percent flowering of soybean was delayed in foliar spray by 1- 2 days under soybean crops as compared to control plots. The 50 % flowering in soybean was varied from 44.00-46.00 DAS.

4.1.5.2 Maturity

Average number of days taken to maturity of soybean in control plots and different foliar spray chemicals and their combinations of soybean crops have been given Table 4.5.

After perusal of the result it is clear that maturity of soybean was not affected significantly in control plots and different foliar spray chemicals and their combinations of soybean crops. The maturity in soybean was varied from 84.00-85.00 days.

Table 4.5: Influence of foliar spray of chemicals in soybean on average number of days to 50% flowering and days taken to maturity for mitigating drought effect

Treatment	Days to 50% flowering	Days taken to maturity
T_1 : Control	44.67	84.67
T_2 : Water spray at 25-30 and 55-60 DAS	46.00	84.67
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	45.33	84.00
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	45.33	85.33
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	45.33	85.33
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	44.67	84.67
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	45.67	84.00
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	46.00	85.00
SEm±	**0.51**	**1.04**
CD (P=0.05)	**1.59**	**3.23**

4.2 Yield attributing characters

4.2.1 Number of pods plant^{-1}

Data on number of pods plant^{-1} as Influenced by different foliar spray of chemicals in soybean are given in Table 4.6 and Figure 8.

It is obvious from the data that number of pods plant^{-1} varied significantly under different treatments. Among all the treatments, the minimum number of pods plant^{-1} were recorded under control plot (23.60) which were increased significantly when foliar spray measure were adopted. The foliar spray of water at 25-30 DAS and 55-60 DAS enhanced the number of pods and significantly superior over control plot (23.60). The foliar spray of 1% KCl solution and thiourea@250g ha^{-1} solution at 25-30 DAS and 55-60 DAS alone enhanced the number of pods appreciably in soybean plant, while the foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS was better than combined foliar

spray of 1% KCl + Trizophos 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS. But foliar spray of 1% KNO_3 + Trizophos@ 600 ml ha^{-1} solution at 25-30 DAS and 55-60 DAS (37.18) had more number of pods $plants^{-1}$ followed by foliar spray of thiourea@250g ha^{-1} + Trizophos 600 ml/ha solution at 25-30 DAS and 55-60(35.51). However, these treatments significantly superior to control plots.

4.2.2 Number of seeds pod^{-1}

Data on seeds pod^{-1} as Influenced by different foliar spray treatments are given in Table 4.6 and Figure 8.

It is obvious from the data that number of seeds pod^{-1} varied significantly under different treatments. Among all the treatments, the minimum number of seeds pod^{-1} were recorded under control plot (2.40) which were increased significantly when foliar spray measure were adopted. The foliar spray of water at 25-30 DAS and 55-60 DAS enhanced the number of seeds pod^{-1} and significantly superior over control plot (2.40). The foliar spray of 1% KCl solution and thiourea@250g ha^{-1} solution at 25-30 DAS and 55-60 DAS alone enhanced the number of seeds pod^{-1} appreciably in soybean plant, while the foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS was better than combined foliar spray of 1% KCl + Trizophos 600 ml ha^{-1} solution at 25-30 DAS and 55-60 DAS. But foliar spray of 1%KNO_3 + Trizophos@ 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS (3.13) had more number of seeds pod^{-1} followed by foliar spray of thiourea@250g ha^{-1} + Trizophos 600ml ha^{-1} solution at 25-30 DAS and 55-60(3.20). However, these treatments significantly superior to control plots.

4.2.3 Number of seeds $plant^{-1}$

Data on seeds $plant^{-1}$ as Influenced by different foliar spray treatments are given in Table 4.6 and Figure 8.

It is obvious from the data that number of seeds $plant^{-1}$ varied significantly under different treatments. Among all the treatments, the minimum number of seeds $plant^{-1}$ were recorded under control plot (56.64) which were increased significantly when foliar spray measure were adopted. The foliar

spray of water at 25-30 DAS and 55-60 DAS enhanced the number of seeds pod^{-1} and significantly superior over control plot (56.64). The foliar spray of 1% KCl solution and thiourea@250g ha^{-1} solution at 25-30 DAS and 55-60 DAS alone enhanced the number of seeds plant^{-1} appreciably in soybean plant, while the foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS was better than combined foliar spray of 1% KCl + Trizophos 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS. But foliar spray of 1% KNO_3 + Trizophos@ 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS (115.91) had more number of seeds plant^{-1} followed by foliar spray of thiourea@250g ha^{-1} + Trizophos 600ml ha^{-1} solution at 25-30 DAS and 55-60(113.04). However, these treatments significantly superior to control plots.

4.2.4 Seed index (g)

Data presented in Table 4.6 and depicted graphically in Figure 8 showed that seed index of soybean was affected due to foliar spray treatments. Among treatments, the minimum seed index (12.68) was recorded in control plot which was significantly increased when foliar spray measures were adopted. The foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS was produced higher seed index as compared to combined foliar spray of 1% KCl + Trizophos 600 ml ha^{-1} solution at 25-30 DAS and 55-60 DAS. Among the combined foliar spray of 1% KNO_3 + Trizophos 600 ml ha^{-1} solution at 25-30 DAS and 55-60 DAS (14.13) produced higher seed index as compared to other foliar spray treatments.

Table 4.6: Influence of foliar spray of chemicals in soybean for mitigating drought effect on different yield attributing characters

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}	Number of seeds plant^{-1}	Seed index (g)
T_1 : Control	23.60	2.40	56.64	12.68
T_2 : Water spray at 25-30 and 55-60 DAS	29.98	2.53	75.40	12.78
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	34.22	2.65	87.42	13.07
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	32.30	2.63	84.90	13.40
T_5 :Foliar spray of thiourea@ 250g ha^{-1} solution at 25-30 and 55-60 DAS	29.99	2.57	79.37	13.53
T_6 :T_5 + Trizophos insecticide@ 600 ml ha^{-1} tank mix	35.51	3.20	113.04	13.46
T_7 :T_4 + Trizophos insecticide@ 600 ml ha^{-1} tank mix	33.32	2.73	90.79	13.66
T_8 :T_3 + Trizophos insecticide@ 600 ml ha^{-1} tank mix	37.18	3.13	115.91	14.13
SEm±	**1.50**	**0.13**	**1.86**	**0.29**
CD (P=0.05)	**4.65**	**0.39**	**5.77**	**0.88**

4.3 Productive parameters

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

Data pertaining to seed yield of soybean (kg ha^{-1}) under different foliar spray treatments are given in Table 4.7 and depicted graphically through figure 9.

It is evident from the data that seed yield significantly varied due to different foliar spray treatments. All the treated plots produced significantly more seed yields than control plots (679.65 kg ha^{-1}). Seed yield was increased

with the foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS 1% KCl solution at 25-30 DAS and 55-60 DAS, and thiourea@250g ha^{-1} and while the combined foliar spray of 1% KNO_3 + Trizophos 600 ml ha^{-1} solution at 25-30 DAS and 55-60 DAS (1390.94 kg ha^{-1}) seed yield was increased at higher magnitude.

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

Data on straw yield (kg ha^{-1}) as affected by different foliar spray treatments are given in Table 4.7 and depicted graphically in Figure 9.

It is evident from the data that straw yield significantly varied due to different foliar spray treatments. All the treated plots produced significantly more straw yield than control plot (2371.12 kg ha^{-1}). Straw yield was increased with the foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS 1% KCl solution at 25-30 DAS and 55-60 DAS, and thiourea@250g ha^{-1} and while the combined foliar spray of 1% KNO_3 + Trizophos 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS (3170.22 kg ha^{-1}) straw yield was increased at higher magnitude.

4.3.3 Harvest index (%)

The ratio of economic yield and biological yield (HI) expressed in percentage was affected by various treatments Table 4.7 and depicted graphically in Figure 9.

Among foliar spray treatments, the minimum harvest index was recorded in control plots (22.28) which was increased the foliar spray of 1% KNO_3 solution at 25-30 DAS and 55-60 DAS, 1% KCl solution at 25-30 DAS and 55-60 DAS and thiourea@250g ha^{-1} being highest (30.47) under combined foliar spray of 1% KNO_3 + Trizophos 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS and proved superior over rest of the treatments.

Table 4.7: Average seed and straw yields of soybean as influenced by foliar spray of chemicals for mitigating drought effect

Treatment	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1 : Control	679.65	2371.12	22.28
T_2 : Water spray at 25-30 and 55-60 DAS	904.76	2876.57	23.92
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	1049.06	3390.39	23.65
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	1018.76	2932.23	25.80
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	952.38	2975.91	24.24
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	1356.42	2953.96	31.46
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	1089.47	3145.85	25.72
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	1390.94	3170.22	30.47
SEm±	**8.11**	**17.32**	**0.46**
CD (P=0.05)	**25.12***	**53.68***	**NS**

4.4 Economic analysis of the treatments

The economic analysis of foliar spray treatments was determined on per hectare area basis, which includes cost of cultivation, gross monetary returns, net monetary returns and benefit cost ratio (profitability per rupee of investment) under different treatments Table 4.8 and Figure 10.

4.4.1 Cost of cultivation (Rs ha^{-1})

Cost of cultivation was determined treatment wise on the basis of market price of various common and variable agro-inputs used [*Appendix –I*(A)]. The values thus obtained are presented in Table 4.8 and Figure 10.

Control plot treatment had the lowest cost of cultivation (Rs 15515.80 ha^{-1}), but it increased in a range of Rs 15795.80 to Rs 16015.80 ha^{-1} and range of Rs 17265.80 to 17645.80 ha^{-1} with the foliar spray of treatment T_2, T_3, T_4 and

T_5 and increased in a range of Rs 17265.80 to 17645.80 ha^{-1} with the increase in combined foliar spray of T_6, T_7, and T_8. As where, it was maximum under T_8 (Rs 17645.80 ha^{-1}).

4.4.2 Gross monetary returns (Rs ha^{-1})

The value of seed and straw yields, depending on the existing market rate of each produce was taken into consideration for determining gross monetary returns (GR) under particular treatment Table 4.8 and Figure 10. The GR was minimum in control plots (Rs 31596.23 ha^{-1}) which increased remarkably under all the plots receiving foliar spray and being maximum under T_3 (1% KNO_3 solution at 25-30 DAS and 55-60 DAS, Rs 48500.05 ha^{-1}). Among the foliar spray treatments, combined foliar spray of treatment T_8 (1% KNO_3+ Trizophos @ 600ml ha^{-1} solution at 25-30 DAS and 55-60 DAS) (Rs 62980.80 ha^{-1}) fetched the highest GR followed by T_6, T_7, T_3, T_4, T_5, T_2 and T_1.

4.4.3 Net monetary returns (Rs ha^{-1})

The net monetary returns (NMR) under each treatment was determined by subtracting the cost of cultivation from GR of the particular treatment. The treatment wise values, thus obtained, are given in Table 4.8 and Figure 10. It was obvious from the data that there was marginal profit of Rs 16080.43 ha^{-1} when crop sown in control plots (T_1) throughout the crop season while maximum NMR was gained from T_8 (Rs 45335.00 ha^{-1}) followed by T_6, T_3, T_7, T_4, T_5, T_2, and T_1.

4.4.4 Benefit - cost ratio

It refers to net monetary gain under a particular treatment with each rupee of investment. The benefit cost indices as affected by different treatments are given in Table 4.8 and Figure 10. It is evident from the data that B:C ratio was maximum under T_8 (3.57) followed by T_6 (3.55), T_3 (3.09), T_4 (2.97), T_7 (2.86), T_5 (2.78), T_2 (2.61), and minimum in T_1 (2.04).

Table 4.8: Gross and net returns of soybean as influenced by foliar spray of chemicals for mitigating drought effect

Treatment	GMR (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C ratio
T_1 : Control	31596.23	15515.80	16080.43	2.04
T_2 : Water spray at 25-30 and 55-60 DAS	41781.33	16015.80	25765.53	2.61
T_3 : Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS	48500.05	15715.80	32784.25	3.09
T_4 :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	46738.86	15755.80	30983.06	2.97
T_5 :Foliar spray of thiourea@250g ha^{-1} solution at 25-30 and 55-60 DAS	43928.29	15795.80	28132.49	2.78
T_6 :T_5 + Trizophos insecticide@600 ml ha^{-1} tank mix	61280.08	17265.80	44014.28	3.55
T_7 :T_4 + Trizophos insecticide@600 ml ha^{-1} tank mix	49992.89	17455.80	32537.09	2.86
T_8 :T_3 + Trizophos insecticide@600 ml ha^{-1} tank mix	62980.80	17645.80	45335.00	3.57
SEm±	-	-	-	-
CD (P=0.05)	-	-	-	-

DISCUSSION

The efficacy of foliar spray of chemicals and their combination were assessed for their effect on crop growth parameters like plant population, branches plant^{-1}, plant height, number of leaves and finally the seed yield has been presented in this chapter and efforts has been made to discuss the reason which may be responsible for some of the important results outlined in the previous chapter. As the yield is the final criteria for the evaluation of the efficiency of different treatments. The discussion therefore is necessarily centered on the effect of treatments on various characters as they finally decided the yield. The results obtained and outlined in the forthcoming pages to reach at a valid conclusion. The findings of this investigation have also been supported with the findings of other research workers and data recorded on various parameters during the course of investigation.

5.1 Edaphic and climatic variation

The cropped area mainly depends on the soil type and climatic conditions of the area, besides the impact of cultural practices followed under particular cropping system. In general fertility status of the soil was identical to the area as the same crop sequence (soybean - wheat) was followed since last five years with recommended dose of fertilizers to both the crops in sequence. The weather conditions which prevailed during the crop season were almost similar to that of average conditions of the locality. The average rainfall (1200.00 mm) and temperature (minimum and maximum mean temperature ranging from 11.27 ^{0}C to 44.14 ^{0}C) during the crop season was almost favourable for optimum growth and development of soybean. However, dry spell occurred during the start of last week of September which was nullified after one life saving irrigation to soybean and the variations that had been observed for various parameters under different treatments were mainly due to treatments effects rather than any other factors.

5.6 Study of plant growth parameters

Data given in Table 4.1 revealed that the plant population per meter square was non significantly due to different foliar spray treatments at 20 DAS and at harvest stage, indicating that the application of water, 1% of KNO_3, 1% of KCl and 1% of thiourea and their combined have no adverse effect on crop plants. The subsequent observation at harvest revealed slight declining trend under all the treatments but a greater drop was recorded in control plots which may be attributed to severe competitional stress by drought, light, moisture and nutrients, resulting in mortality of some of the crop plants (Singh and Rao,1993).

Plant height of soybean did not vary due to treatments at early growth stage (20 DAS) of crop (Table 4.2). But during advanced stages (40, 60 and at harvest) it was affected significantly by various treatments. The plant height of soybean considerably more under T_8 (1% of KNO_3 + Trizophos@600 ml ha^{-1}) 52.24, 74.83, & 76.20 cm at 40, 60 DAS, and harvest, respectively as compared to control plots this may be due to moisture stress and all the growth resources were optimally utilized by the crop plants. However, all the foliar spray chemicals treatments showed better plant height over control plots. The excellent growth under these treatments led to optimal utilization of growth resources, therefore, these treatments have long statured plants. These results are in close conformity with the finding of Ramesh and Thirumurugan (2001).

Number of leaves plant^{-1} remarkably differed due to different treatments at various growth intervals of crop (20, 40 and 60 DAS). The number of leaves plant^{-1} were less (7.09, 16.01 & 13.80 at 20, 40 & 60 DAS, respectively) and decrease number of leaves plant^{-1} at stage of 60 DAS of all treatment. (Table 4.3) when foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS was applied the higher number of leaves plant^{-1} 17.47 at harvest stage, followed by foliar spray of thiourea@250g solution at 25-30 and 55-60 DAS. Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS resulted in increased in the number of leaves plant^{-1} at all the stages. This may be attributed to increased leaves during critical period of crop growth as a result of effective number of leaves on soybean seedlings. But found significantly inferior to that of (1% of KNO_3 +

Trizophos@600 ml ha^{-1}) (9.09, 20.74 & 18.53 at 20, 40 and 60 DAS respectively) followed by T_7 (thiourea@250g + Trizophos@600 ml ha^{-1}) (8.52, 19.40, & 17.20 at 20, 40 and 60 DAS respectively) because, both the treatments provided excellent growth which, led to optimum growth and development of crop plants and ultimately resulted in more number of leaves $plant^{-1}$ under these treatments. Almost similar results were obtained by Bly et al. (1996).

Branches $plant^{-1}$ remarkably differed due to different treatments at various growth intervals of crop (20, 40 and 60 DAS). The number of branches $plant^{-1}$ were less (2.12, 2.92 & 3.57 at 20, 40 & 60 DAS, respectively) (Table 4.4) when foliar spray of thiourea@250g solution at 25-30 and 55-60 DAS was applied the higher branches of plant 3.85 at harvest stage, followed by foliar spray of 1% KCl solution at 25-30 and 55-60 DAS. Foliar spray of 1% KNO_3 solution at 25-30 and 55-60 DAS resulted in increased in the number of branches $plant^{-1}$ at all the stages. This may be attributed to increased growth during critical period of crop growth as a result of effective crop growth on soybean seedlings. But found significantly inferior to that of (1% of KNO_3 + Trizophos@600 ml ha^{-1}) (2.85, 3.65 & 4.31 at 20, 40 and 60 DAS respectively) followed by T_7 (thiourea@250g + Trizophos@600 ml ha^{-1}) (2.64, 3.44, & 4.10at 20, 40 and 60 DAS respectively) because, both the treatments provided excellent growth which, led to optimum growth and development of crop plants and ultimately resulted in more number of branches $plant^{-1}$ under these treatments. Almost similar results were obtained by Reddy et al. (2004).

5.7 Effect on yield attributing characters of crop

The yield attributing traits namely pods $plant^{-1}$, seed pod^{-1} and seed index (100 seed weight) were superior under (T_8) 1% of KNO_3 + Trizophos@600 ml ha^{-1} (40.79 & 14.13 respectively) receiving two foliar spray at 25-30 & 55-60 DAS followed by combined application of T_3 and T_7 over control plots, but seeds per pod were mostly similar in all the treatments (Table 4.6). Excellent growth and development of soybean plants under foliar spray during critical period of crop growth might have resulted in superior yield

attributes under T_8 treatment as compared to T_1, T_2, T_3, T_4, T_5, T_6 and T_7, which had severe foliar spray chemicals right from early growth stages and ultimately resulted in most inferior yield attributes. Almost similar results were obtained by Shindhe and Jadhav (1995) and Rahul and Parhe (2015).

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

Seed yield under a particular treatment is the result of complex phenomenon, which not only depends on the genetic constitution of the crop plants but also on the production technology adopted. The seed yield was lowest (679.65 kg ha^{-1}) in the plots receiving control plots due to severe competition stress right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the seed yield (Table 4.7). All the treated plots receiving either manual foliar spray treatments produced higher yield over control plots. Combined foliar spray treatment produced the maximum seed yield (1390.94 kg ha^{-1}) and proved its superiority over all the treatments. The crop under treated treatment attained lush growth due to elimination of problems from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and development, and consequently the highest yield. Sathiyamoorthy and Vivekanandana (1988), Govindan and Thirumuragan (2000).

5.9 Harvest index (%)

Harvest index (the ratio of economic yield to the biological yield) was significantly higher under T_6 (31.46%) closely followed by T_8 (30.47%), T_4, T_7 ,T_5, T_3, T_2 and T_1. Excellent growth and development of soybean plants under free environment during critical period of crop growth might have resulted in higher harvest index under these treatments (Table 4.7). While, control plots resulted in the lowest value of H.I. (22.28%). The control plots in resulted in stressful condition and ultimately suppress the growth and development of soybean plants.

5.11 Economic viability of treatments

Cost of cultivation play an important role in deciding the acceptability of any treatment by the farmers. It was obvious from the data that foliar spray treatment receiving two spray at 25-30 and 55-60 DAS, required maximum variable cost (Rs 17645.80 ha^{-1}), which was not affordable by the poor farmers and at the same time availability of laboures during peak period is also not certain (Table 4.8). Thus, use of foliar spray chemicals seems to be cheaper.

The gross monetary returns (GMR) was minimum (Rs 31596.23 ha^{-1}) under control plots because of the lowest seed and straw yields (Table 4.8). But it was increased to a maximum level (Rs 62980.80 ha^{-1}) under T_8 treatments received two spray at 25-30 and 55-60 DAS closely followed by foliar spray (T_6) (Rs 61280.08 ha^{-1}) and T_7, T_3, T_4, T_5, T_3, T_2 and T_1 also found superior and fetched the greater GMR over weedy check because of increased seed and straw yields of the soybean crop.

Net monetary returns was found minimum (Rs 16080.43 ha^{-1}) under control plots treatment, but increased to a maximum level (Rs 45335.00 ha^{-1}) under T_8 treatment closely followed by $T_{6,}$ $T_{3,}$ T_7 and $T_{4,}$ as Rs 44014.28 ha^{-1}, Rs 32784.25 ha^{-1}, Rs 32537.09 ha^{-1} and Rs 30983.06 ha^{-1} respectively (Table 4.8). The low investment and better seed and straw yields coupled with good economic returns might be the reason for higher NMR over remaining treatments *viz*., T_5, T_2 and T_1. However, these foliar spray treatments were found superior over control plots treatment and fetched higher NMR of Rs 45335.00 ha^{-1}, Rs 44014.28 ha^{-1}, 32784.25 ha^{-1}, Rs 32537.09 ha^{-1} and Rs 30983.06 ha^{-1} respectively.

The benefit-cost ratio represents the profitability of the treatments. The B:C ratio refers that total monetary gain under a particular treatment with each rupee of investment. The benefit per rupee of investment was lowest (2.04) in plot receiving control plots (T_1) which was increase appreciably in plot receiving foliar spray measures either through chemicals, (Table 4.8). The foliar spray of water caused slight improvement in the B:C ratio (2.61) and also application of foliar spray of 1% KCl and thiourea@250g caused slight improvement in the B:C ratio (2.97 and 2.78) which increase due to application of foliar spray of 1%

KNO_3 (3.09) due to proportionate increase in profit per rupee of investment on foliar spray. The combined foliar spray of 1% KNO_3 + Trizophos@600g ha^{-1} as recorded the maximum benefit (3.57) due to more gain each rupee of investment. However, GMR value was more under T_8, it had more B:C ratio (3.57) followed by T_6 treatment due to improportionate increase in profit to that of investment.

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

Soybean is an important oilseed crop and playing a vital role in sustaining the oilseed production in India over the past few years. In the different constraints, the weed management assumes the major importance for increasing the productivity of soybean. Intensive use of agro-chemicals coupled with congenial edaphic and weather conditions during *Kharif* season further aggravate the weed manage, other factor resulting into low yields of soybean.

A field experiment was conducted during kharif season of 2015, AICRP for Dryland Agriculture, Kuthulia Farm College of Agriculture, Rewa (M.P.) to study the "Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition*."* Keeping above facts in view, present study has been taken with following objectives:-

Objectives of Investigation:

1. To assess the growth and development of soybean as influence by different chemicals spray.
2. To find out the suitable chemical to mitigate drought in soybean.
3. To judge the comparative performance of different chemicals and water spray from control on the basis of economics of treatments.

The present experiment was carried out on clayey soil which was medium in organic carbon (0.60 %), available nitrogen (350 kg ha^{-1}) and phosphorus (16.50 kg ha^{-1}) but high in potassium (333 kg ha^{-1}) and neutral in reaction (7.1). The investigation was aimed to study the efficacy of drought effect through foliar spray of chemicals and to determine economic viability of treatments. Eight treatments comprised of water spray,1% KNO_3, 1% KCl, thiourea@250g ha^{-1} and their combination with trizophos at 25-30 and 55-60 DAS and control plots were laid out in Randomized Block Design with three replications. All foliar spray chemicals treatments were applied in 500 liters of

water per hectare, using flat fan nozzle. Different observations on the crop parameters were carried out during the course of investigation. Plant population of soybean was recorded at 20 DAS and at harvest. Growth parameters viz., plant height (cm), number of branches plant^{-1}, number of leaf were recorded at different time intervals. Yield attributing traits viz., pods plant^{-1}, seeds pod^{-1} and seed index (100 seed weight) were recorded at maturity. Finally, seed and straw yields were recorded treatment wise. Tabulation and statistical analysis of data were done for testing the significance among the different treatments which are summarized below.

6.1.1 Effect on crop

The plant population of soybean was not affected under all treatments at 20 DAS and harvest, indicating that these treatments did not adversely affect the germination and further survival of crop plants. Consequently, plant population was almost similar under all treatments. Growth parameters like plant height, branches plant^{-1}, number of leaves plant^{-1} were significantly superior in treated plot than control plots. However, foliar spray treatment was better overall treatments closely followed by T_3. Yield attributing traits viz., pods plant^{-1} and seed index (100 seed weight) were also superior under treated plots as compared to control plots in which these parameters were inferior.

Both seed and straw yields were significantly higher under all the treatments receiving foliar spray measure than control plots. Maximum seed yield of soybean was recorded under T_8 treatment and proved superior over all the treatments except foliar spray 1% KNO_3 + Trizophos@600ml ha^{-1} (T_8) which was found significantly superior over all the treatment.

6.1.2 Economic viability of treatments

Foliar spray chemical treatments received T_8 maximum investment (Rs 17645.80 ha^{-1}) to control weeds, while expenditure incurred under treatment (T_2) water, (T_3) 1% KNO_3, (T_4) 1% KCl, (T_5) thiourea@250g ha^{-1} and (T_6), (T_7) and (T_8) combination with trizophos at 25-30 and 55-60 DAS ranged from Rs 15515.80 ha^{-1} to Rs 17645.80 ha^{-1}, Maximum gross monetary return (Rs

62980.80 ha^{-1}) was obtained under foliar spray treatment closely followed by T_8 1% KNO_3 + Trizophos@600ml ha^{-1} though GMR was maximum in foliar spray treatments, but the net monetary returns and B-C ratio were also the highest under 1% KNO_3 + Trizophos@600ml ha^{-1} (T_8) closely followed by (T_6) thiourea@250g + Trizophos@600 ml ha^{-1} to soybean.

6.2 Conclusions

Based on the results the following conclusions could be drawn.

1. Growth and development was better in T_8 (foliar spray of 1% KNO_3+ trizophos@600 ml ha^{-1}).
2. The foliar spray of Thiourea@250g ha^{-1} and 1% KNO_3 is the suitable chemical to mitigating drought in soybean.
3. The grain yield (1390.94 kg ha^{-1}), net returns Rs45335 ha^{-1} and B:C ratio 3.57 were maximum under foliar spray of 1% KNO_3 at 25-30 and 55-60 DAS + Trizophos@600 ml ha^{-1} tank mix compared to other treatments.

6.3 Suggestions for Further Work

1. The experiment needs to be tested on the same site and other location for at least 2-3 years to conform the present findings.

2. 1% KNO_3 should also be tested with other compatible chemicals at different rates in soybean.

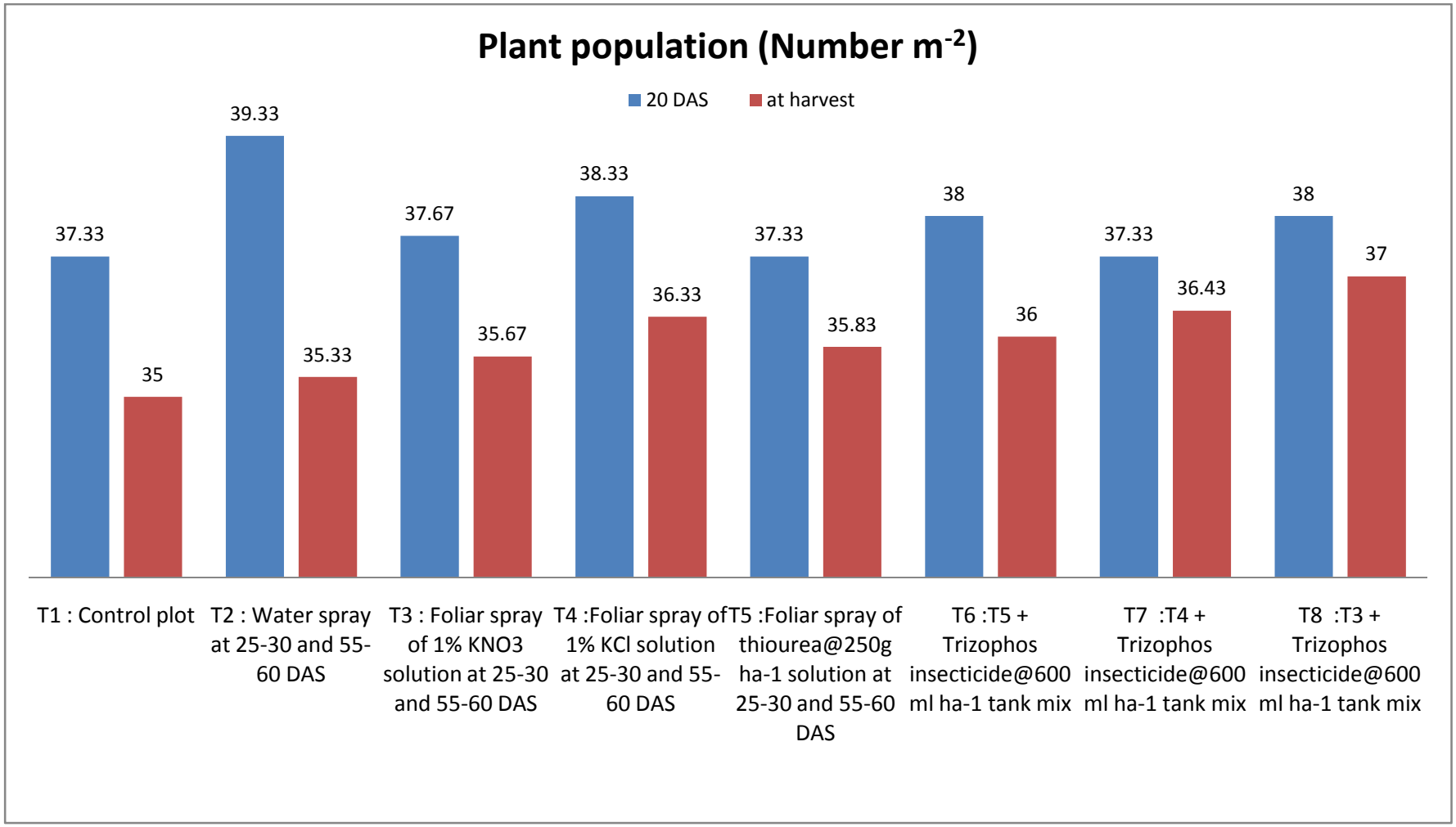

Fig. 3: Influence of foliar spray of chemicals in soybean on average plant population for mitigating drought effect

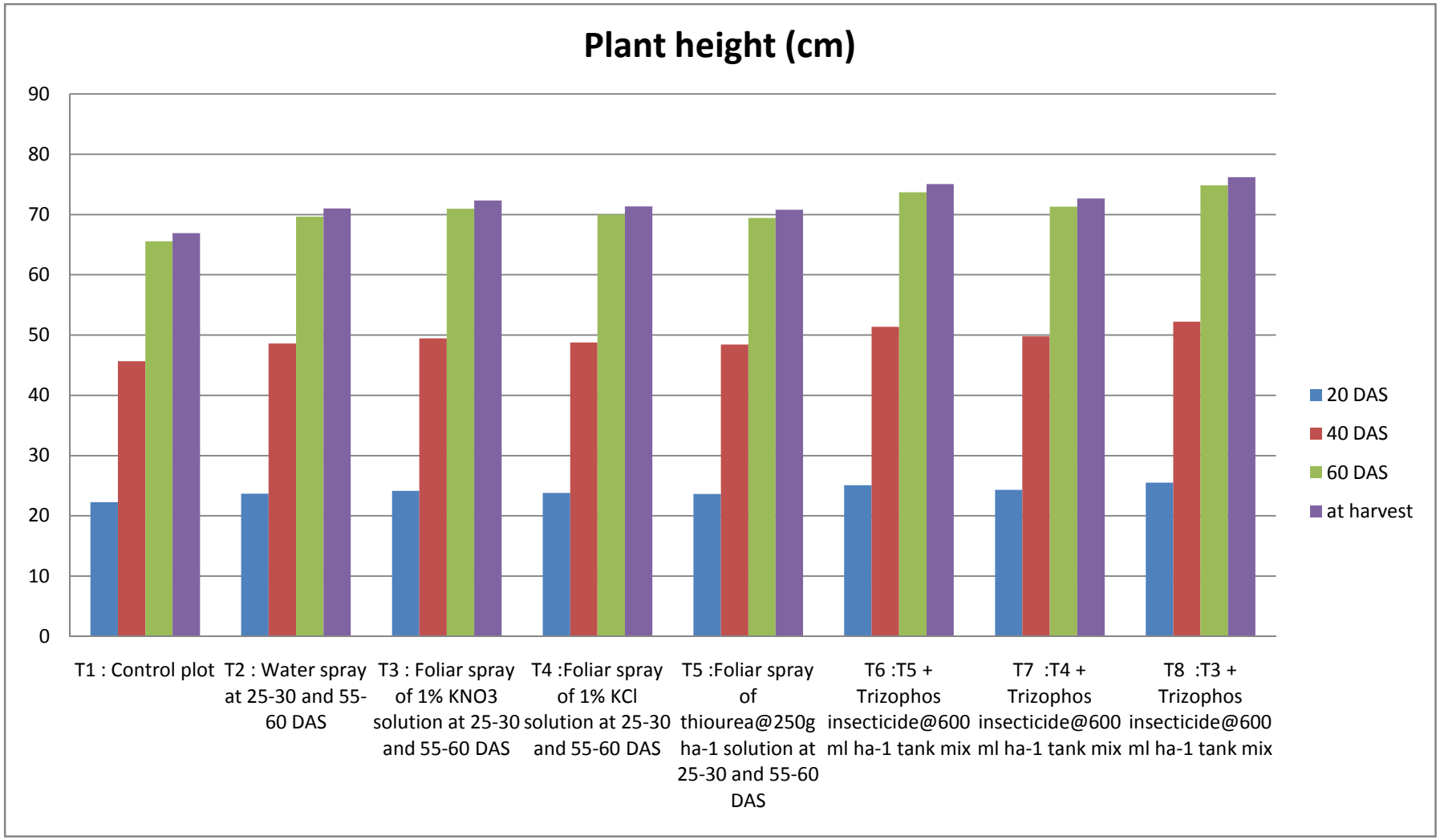

Fig. 4: Influence of foliar spray of chemicals in soybean on average plant height for mitigating drought effect

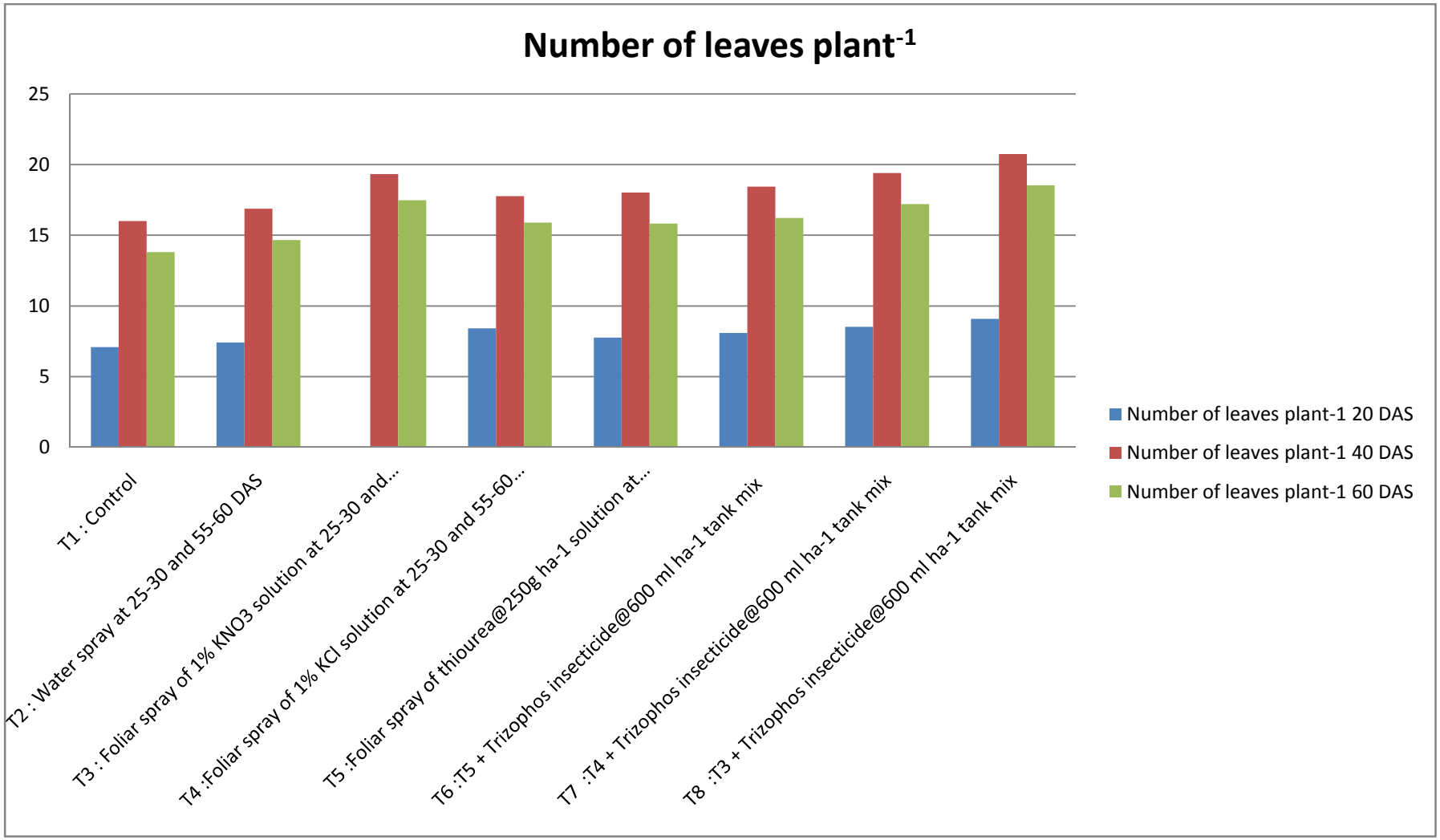

Fig. 5: Influence of foliar spray of chemicals in soybean on average number of leaves plant^{-1} for mitigating drought effect

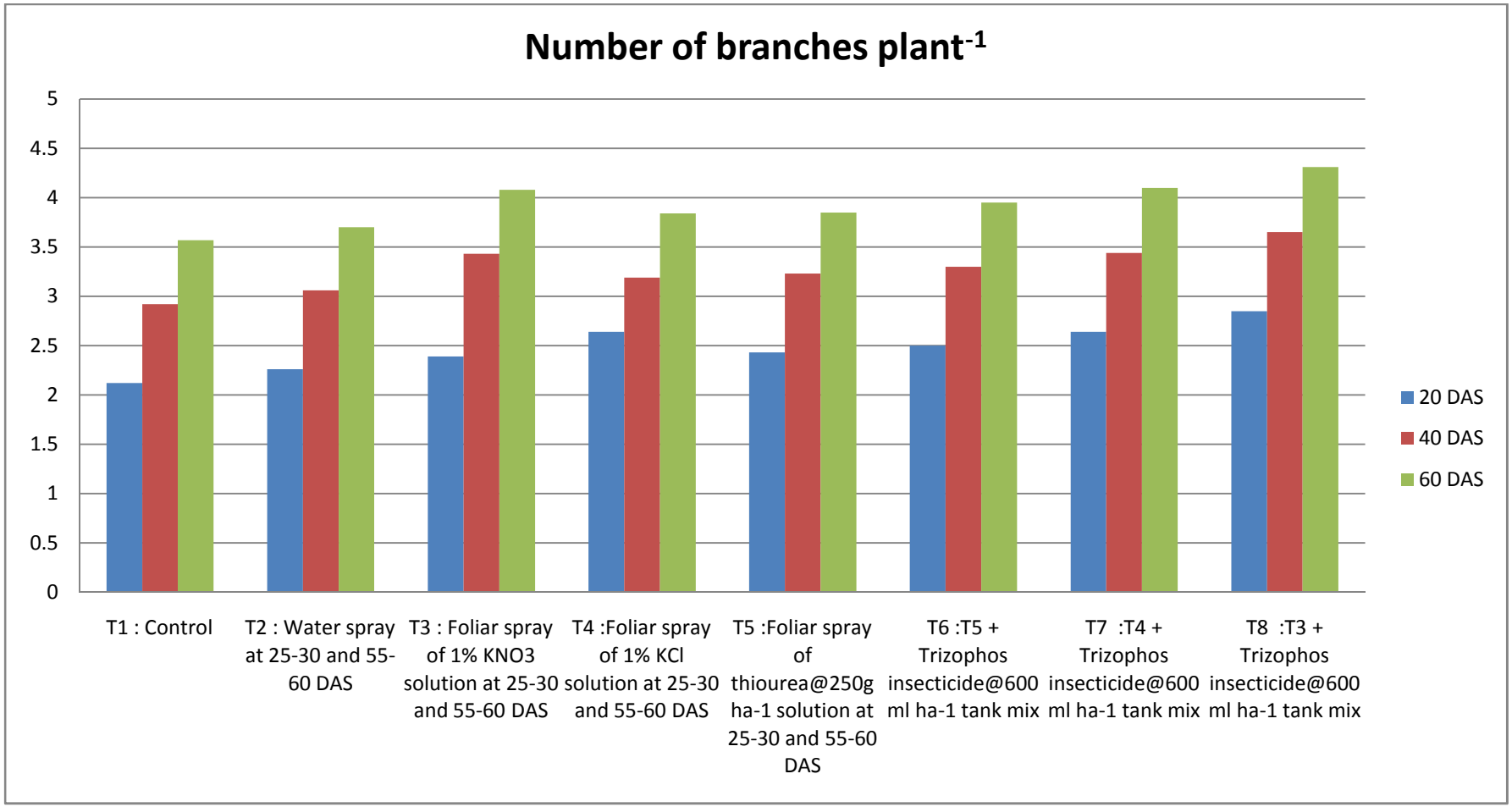

Fig. 6: Influence of foliar spray of chemicals in soybean on average number of branches plant^{-1} for mitigating drought effect

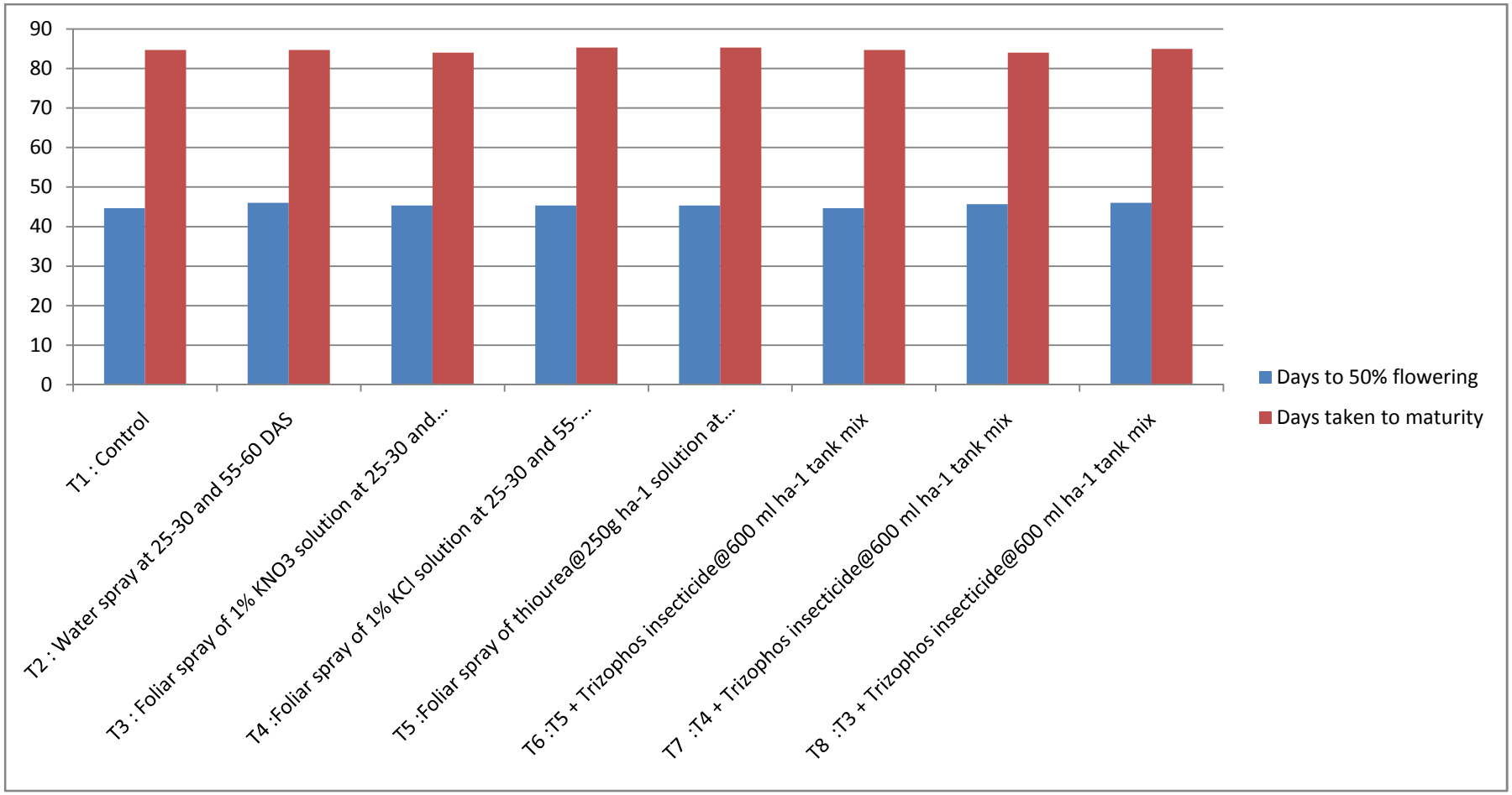

Fig.7: Influence of foliar spray of chemicals in soybean on average number of days to 50% flowering and days taken to maturity for mitigating drought effect

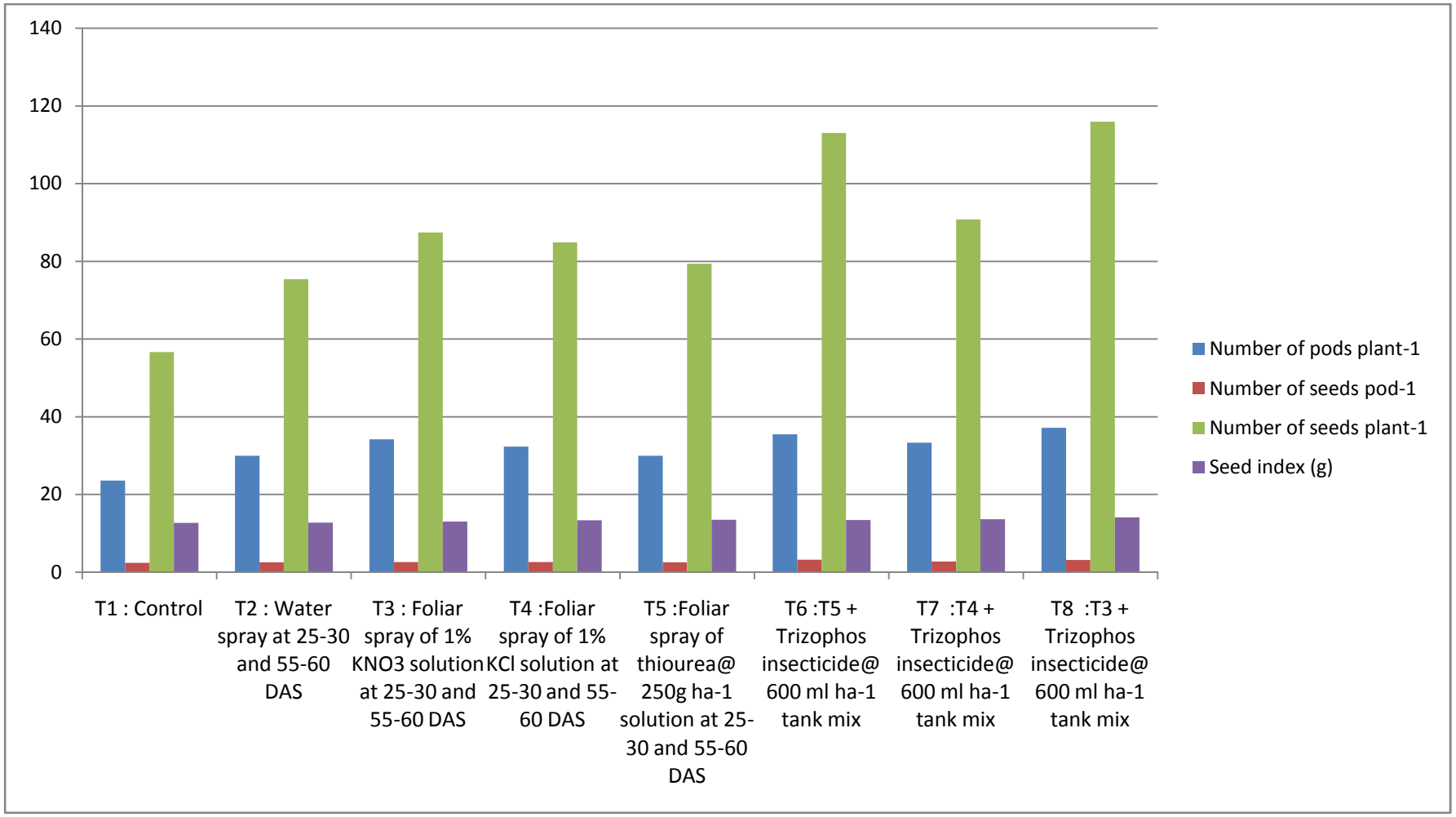

Fig. 8: Influence of foliar spray of chemicals in soybean for mitigating drought effect on different yield attributing characters

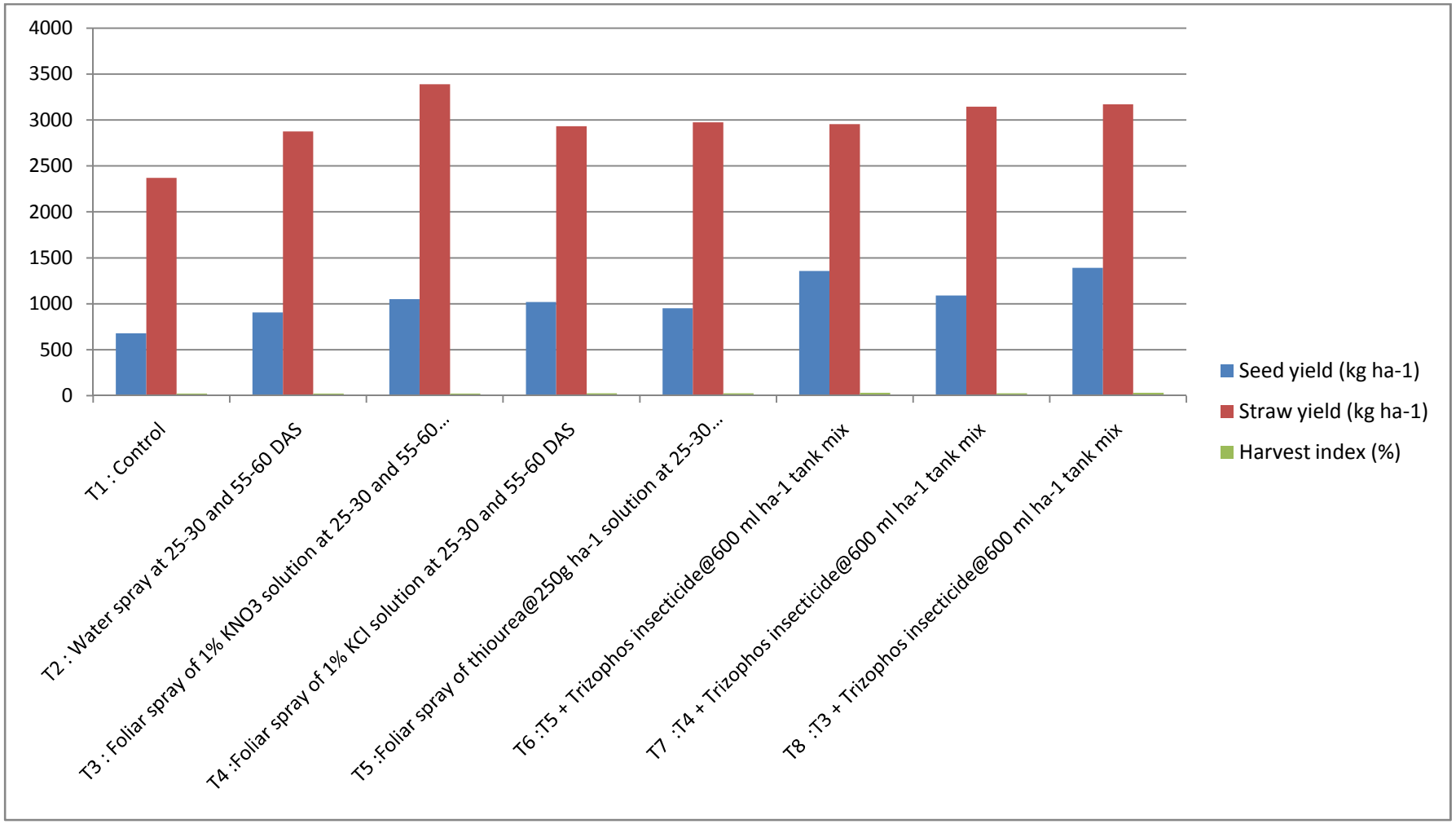

Fig. 9: Average seed and straw yields of soybean as influenced by foliar spray of chemicals for mitigating drought effect

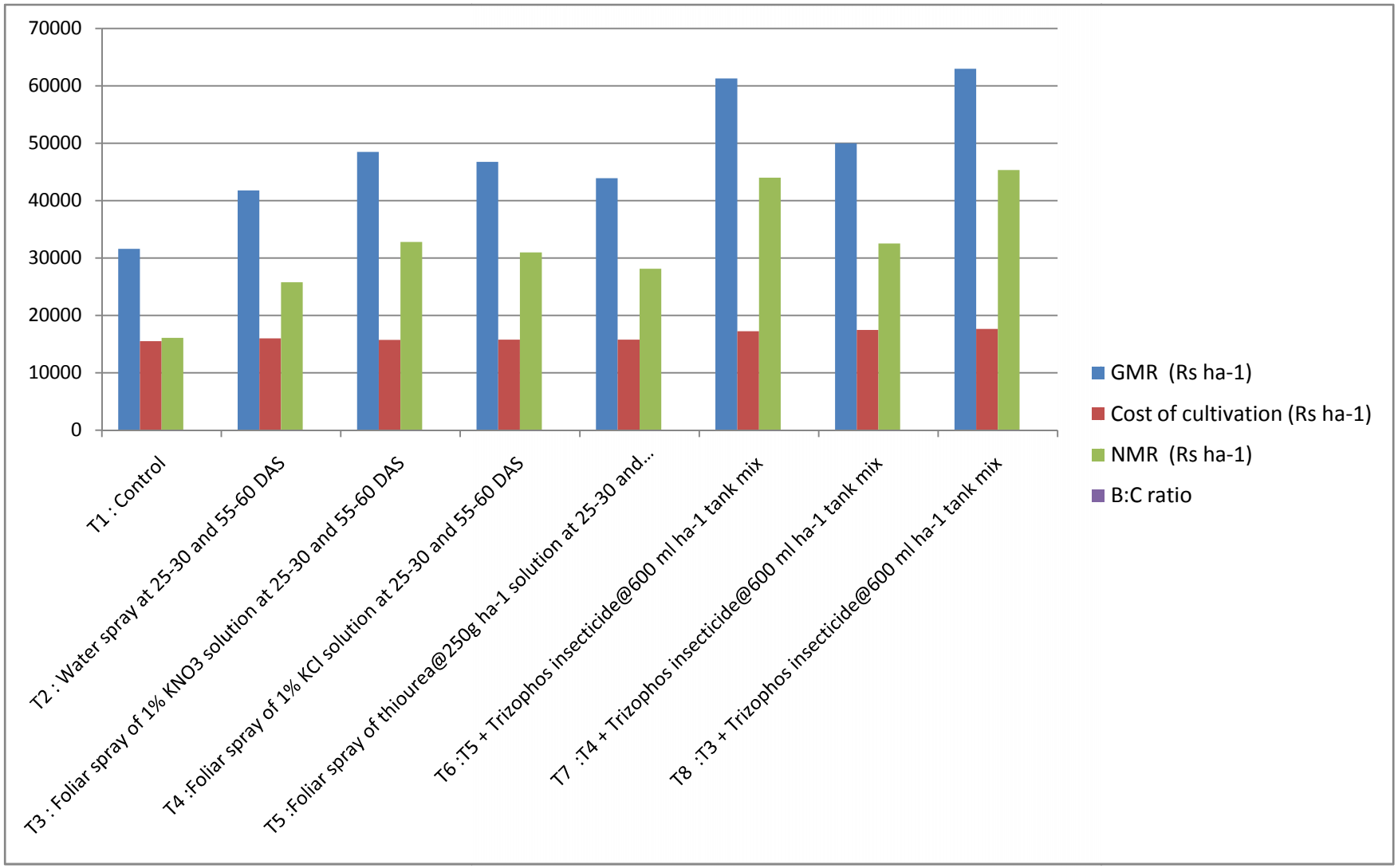

Fig. 10: Gross and net returns of soybean as influenced by foliar spray of chemicals for mitigating drought effect

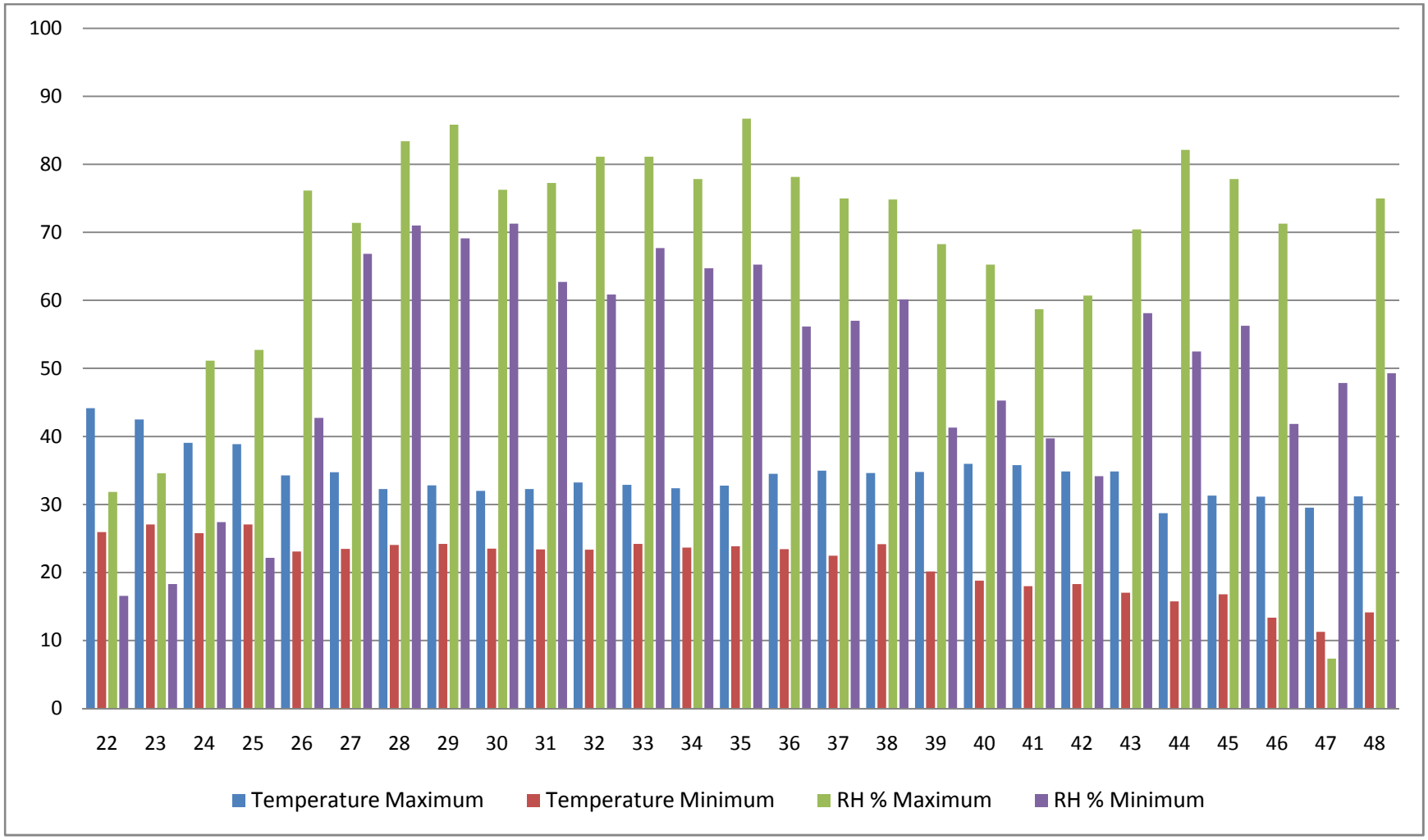

Fig.1: Standard Weekly Meteorological data during crop season of 2015

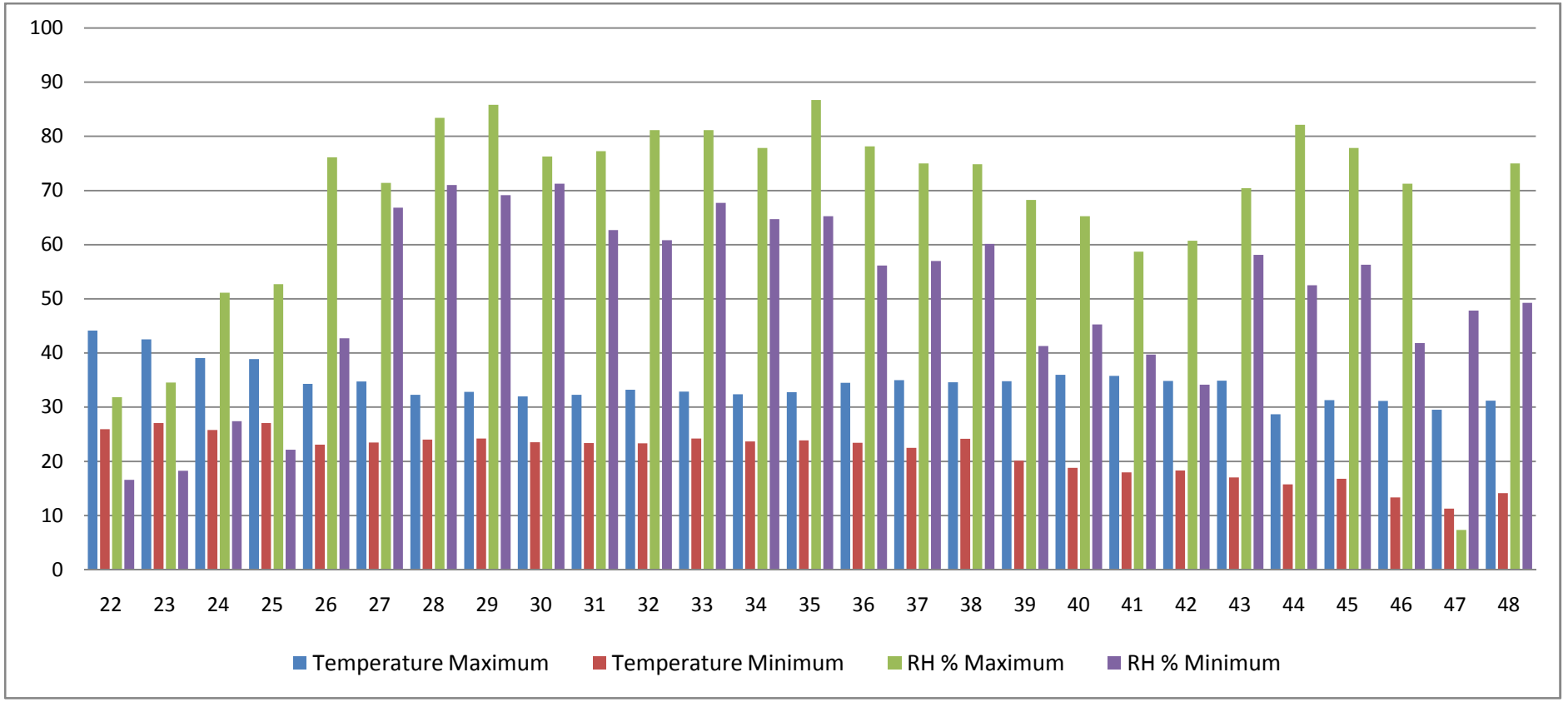

Fig.1: Standard Weekly Meteorological data during crop season of 2015

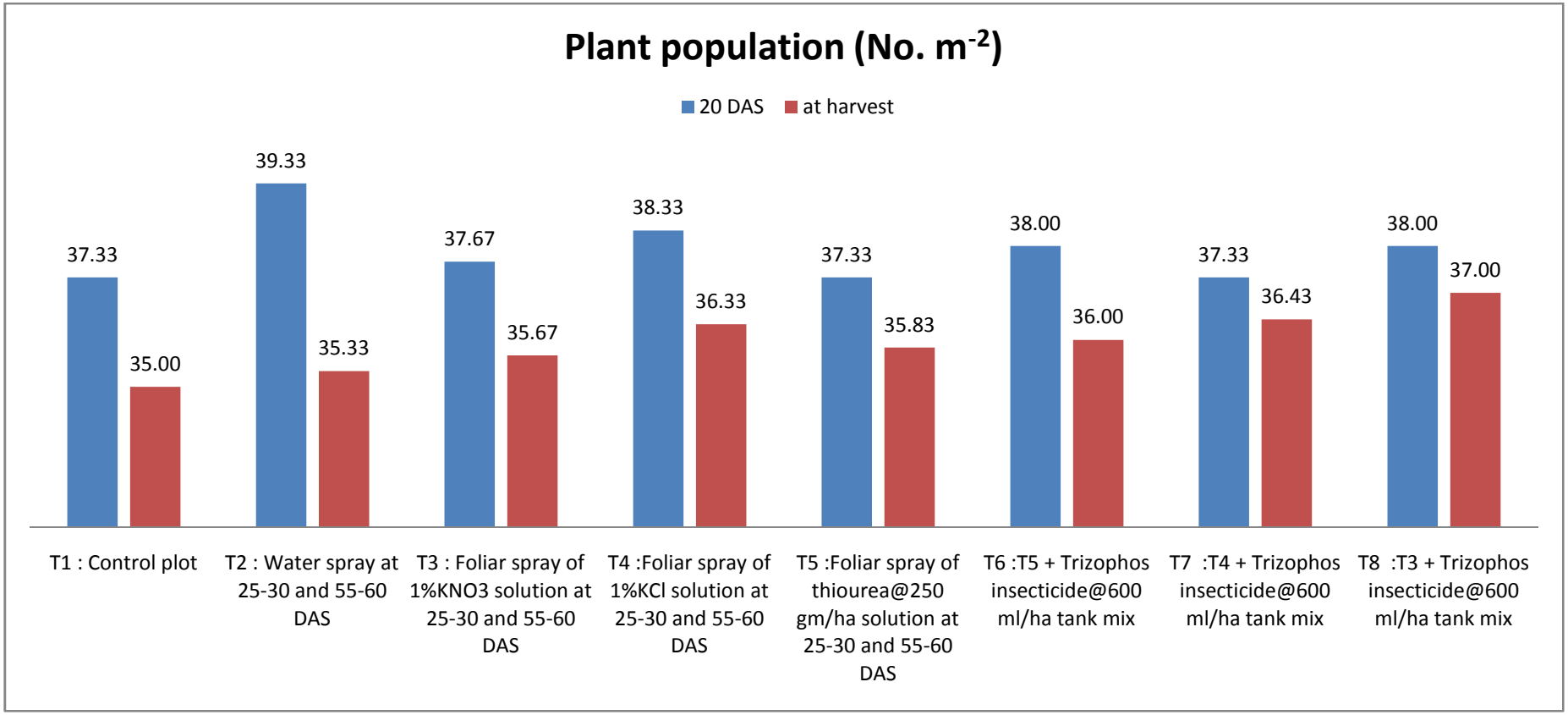

Fig. 3: Influence of foliar spray of chemicals in soybean on average plant population for mitigating drought effect

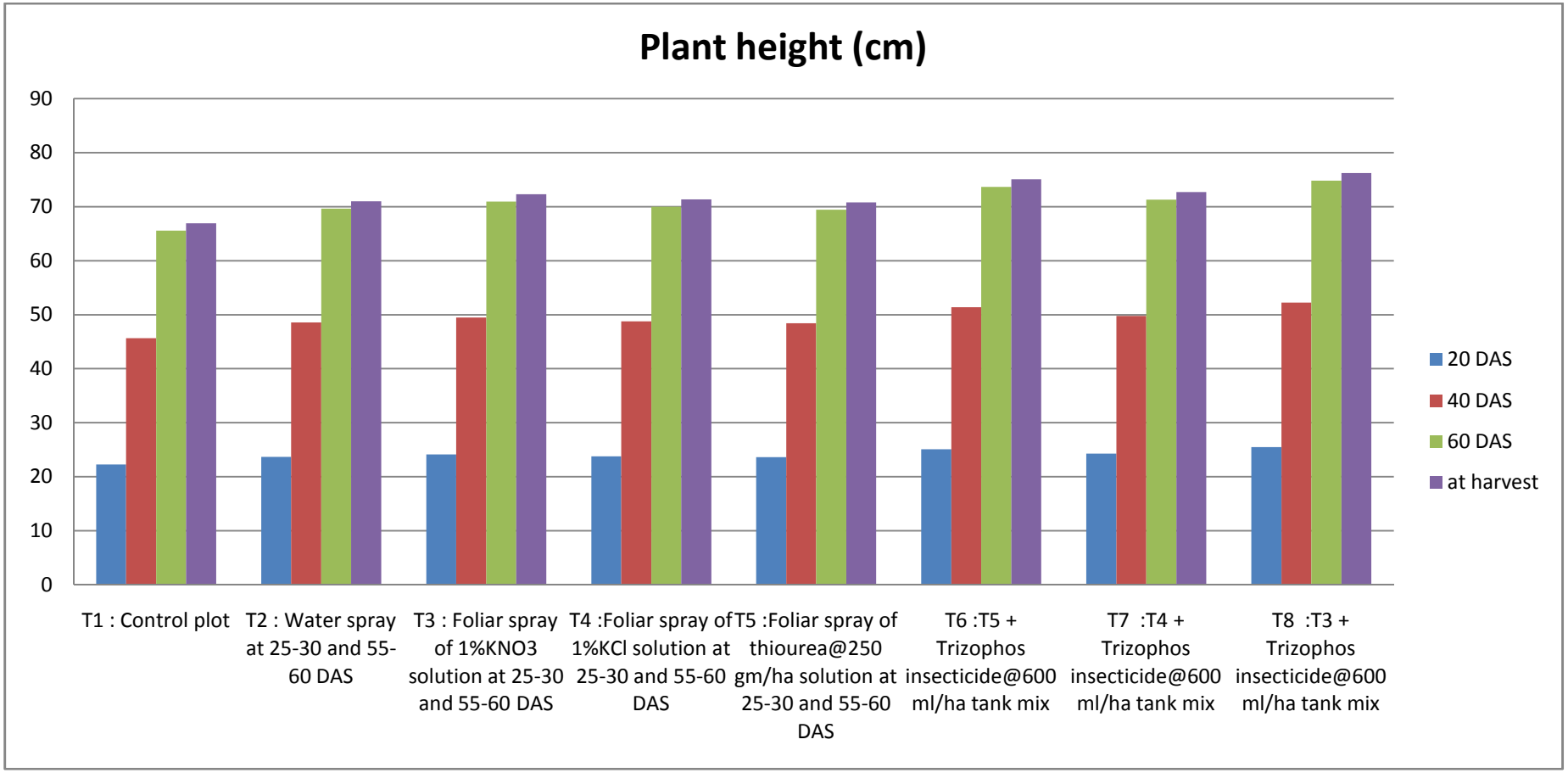

Fig. 4: Influence of foliar spray of chemicals in soybean on average plant height for mitigating drought effect.

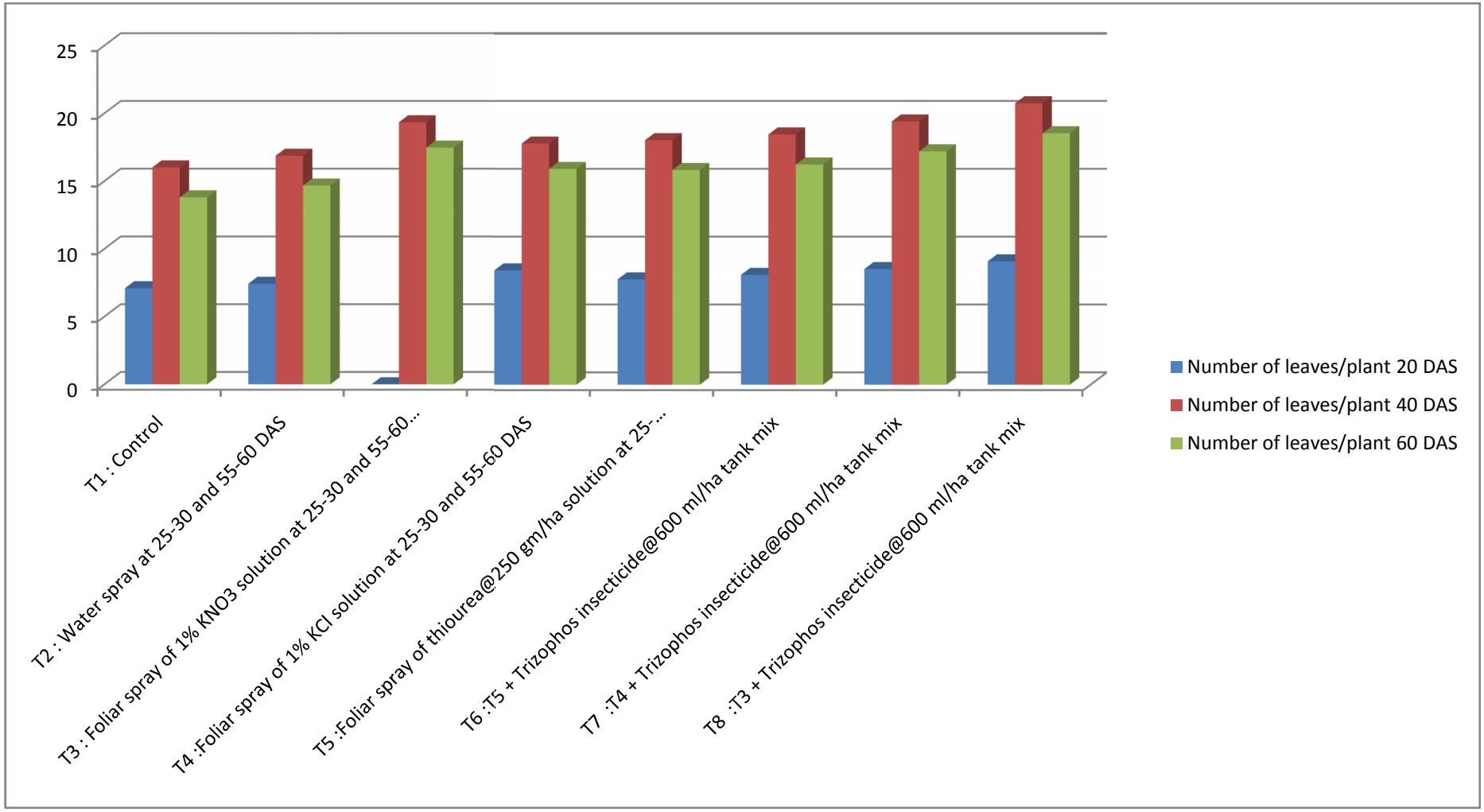

Fig.5: Influence of foliar spray of chemicals in soybean on average number of leaves/plant for mitigating drought effect

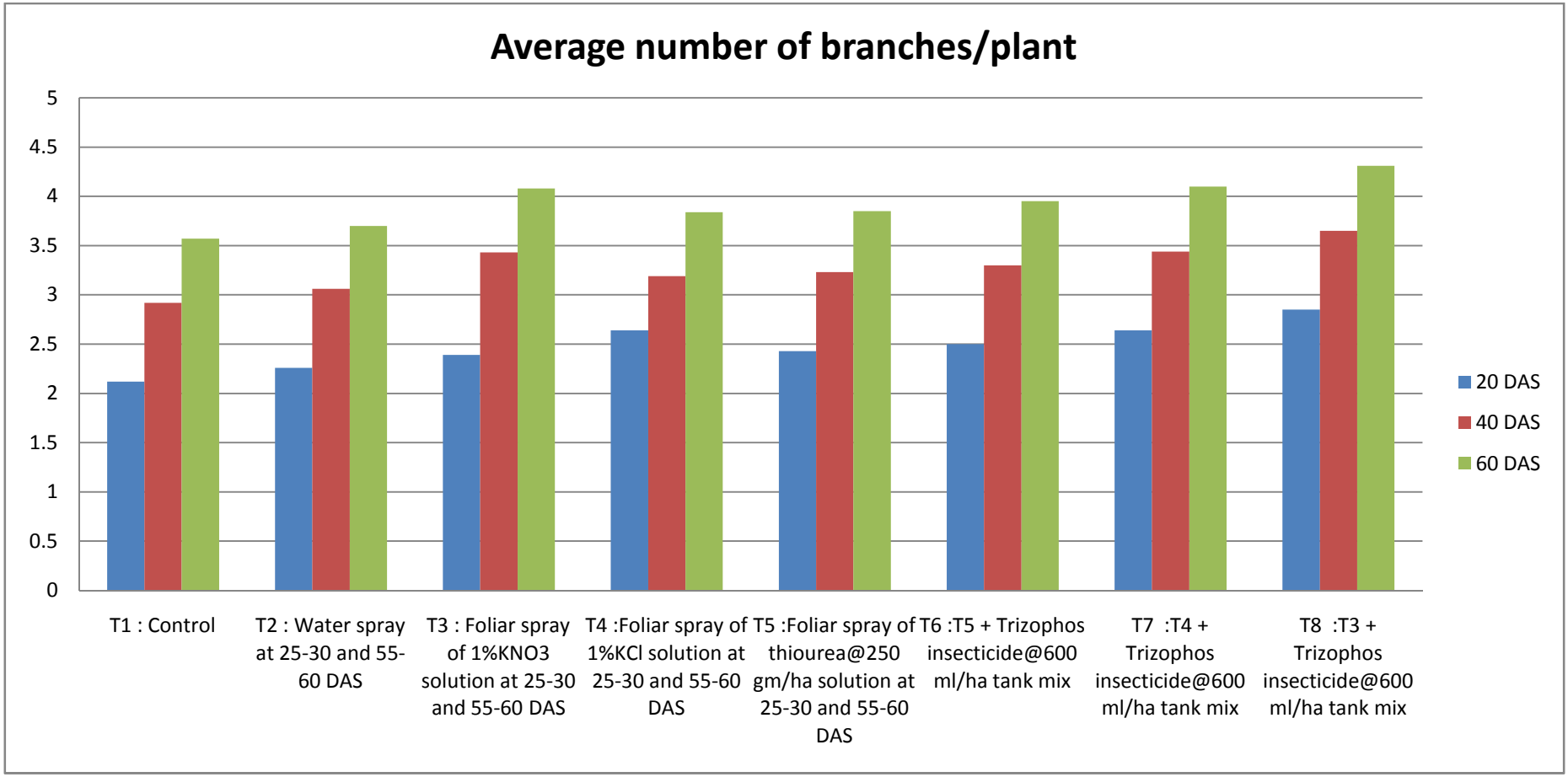

Fig. 6: Influence of foliar spray of chemicals in soybean on average number of branches/plant for mitigating drought effect

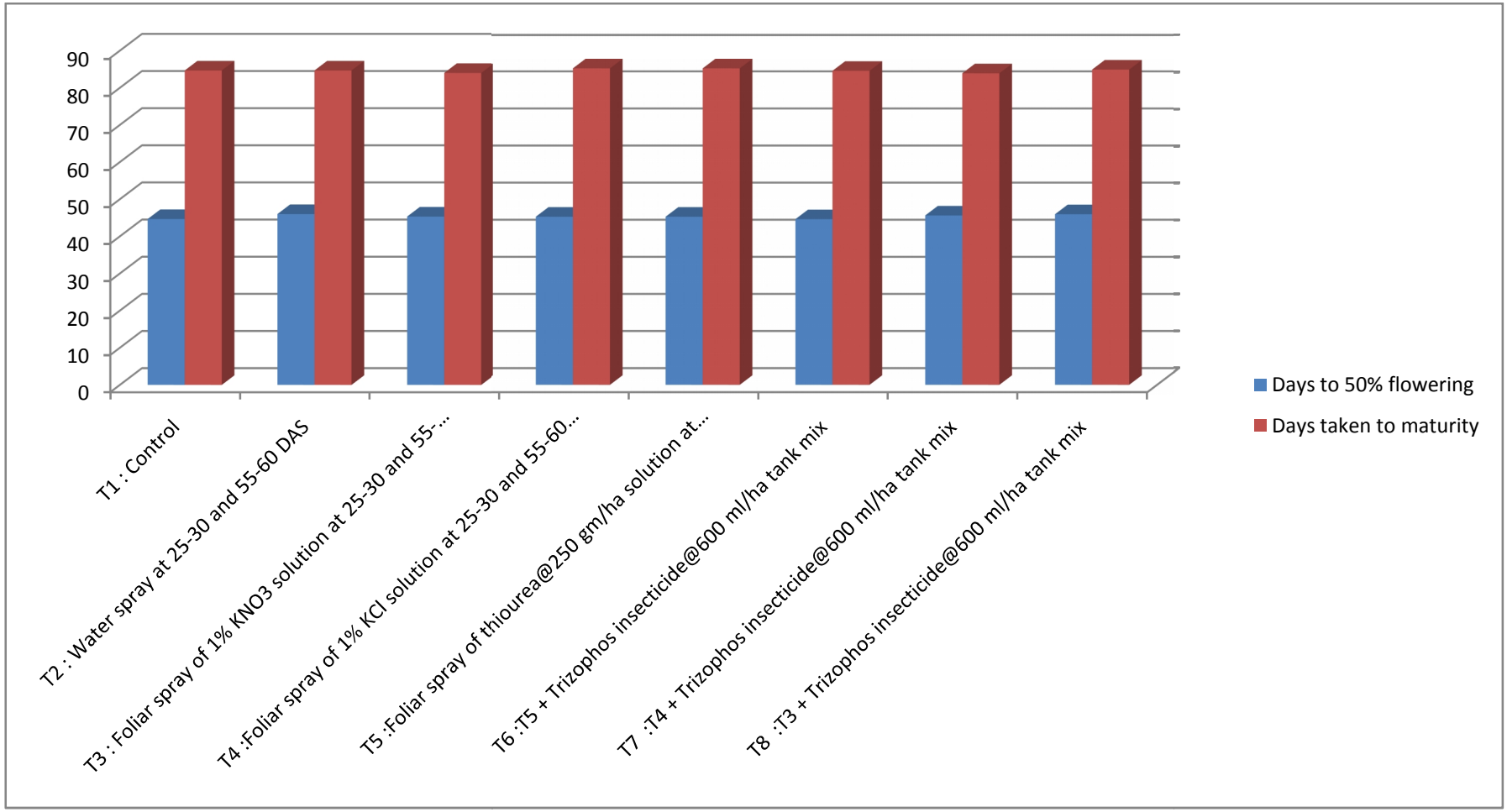

Fig.7: Influence of foliar spray of chemicals in soybean on average number of days to 50% flowering and days taken to maturity for mitigating drought effect.

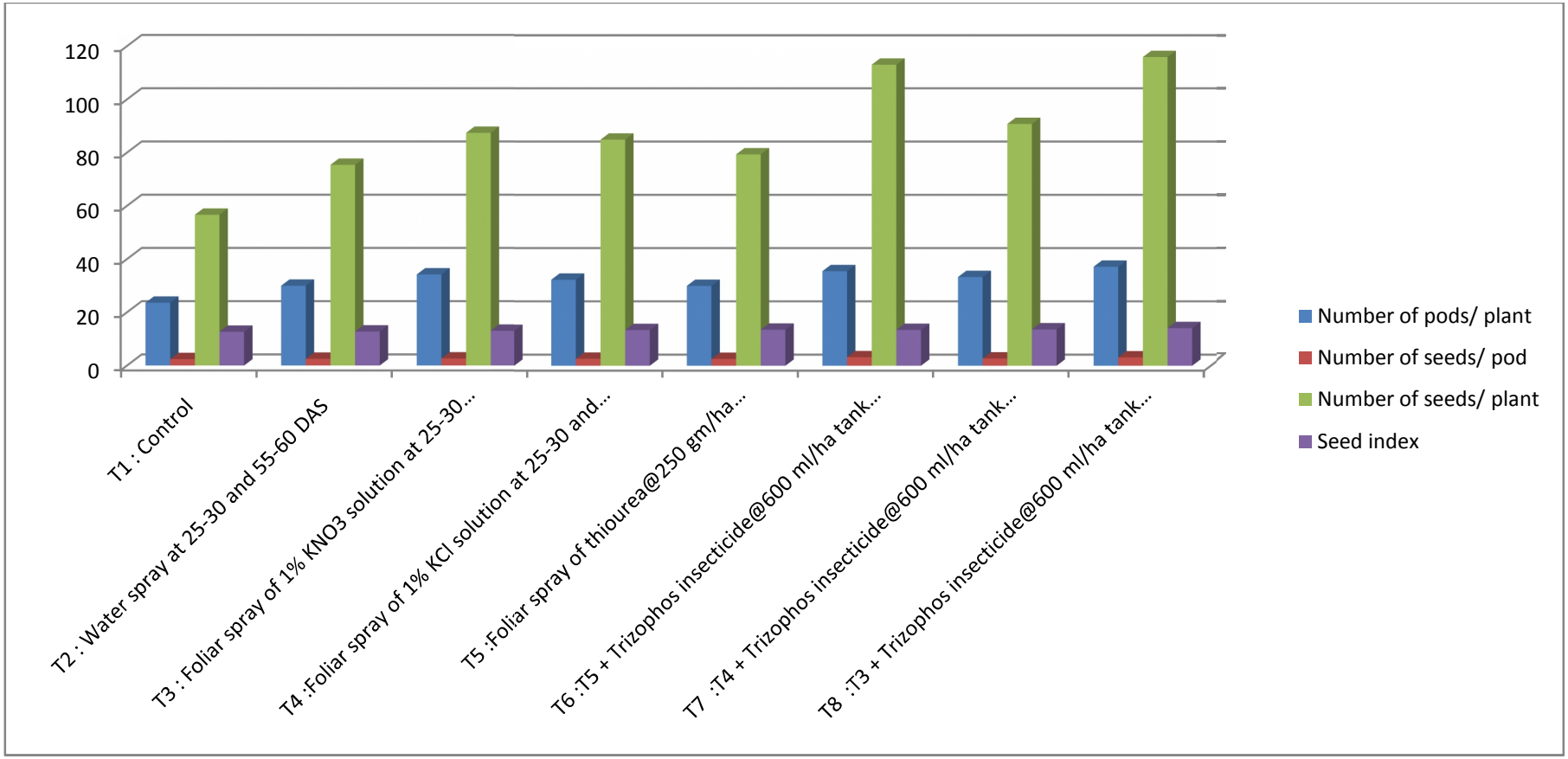

Fig. 8: Influence of foliar spray of chemicals in soybean for mitigating drought effect on different yield attributing character

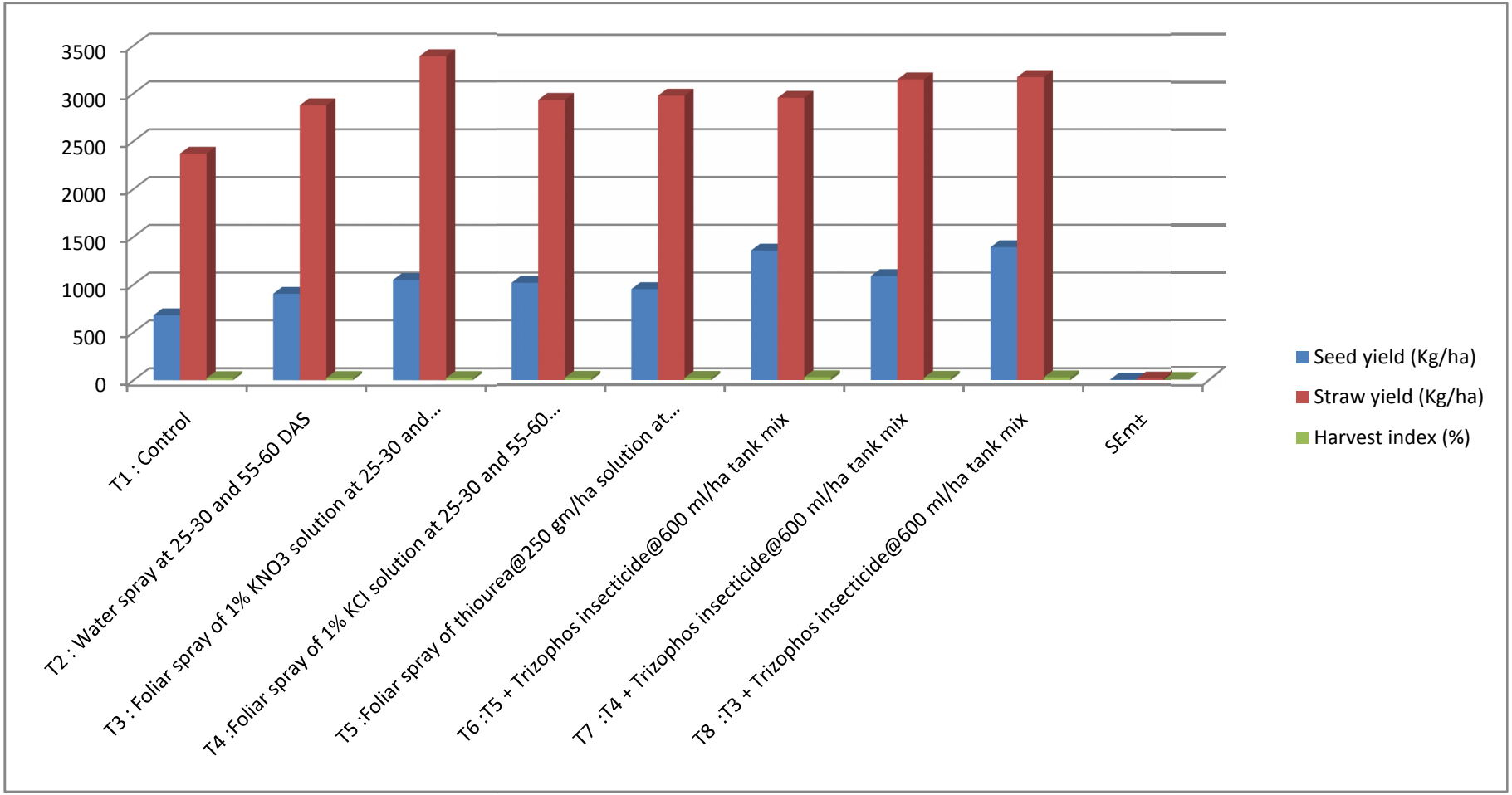

Fig.9: Average seed and straw yield of soybean as influenced by foliar spray of chemicals for mitigating drought effect.

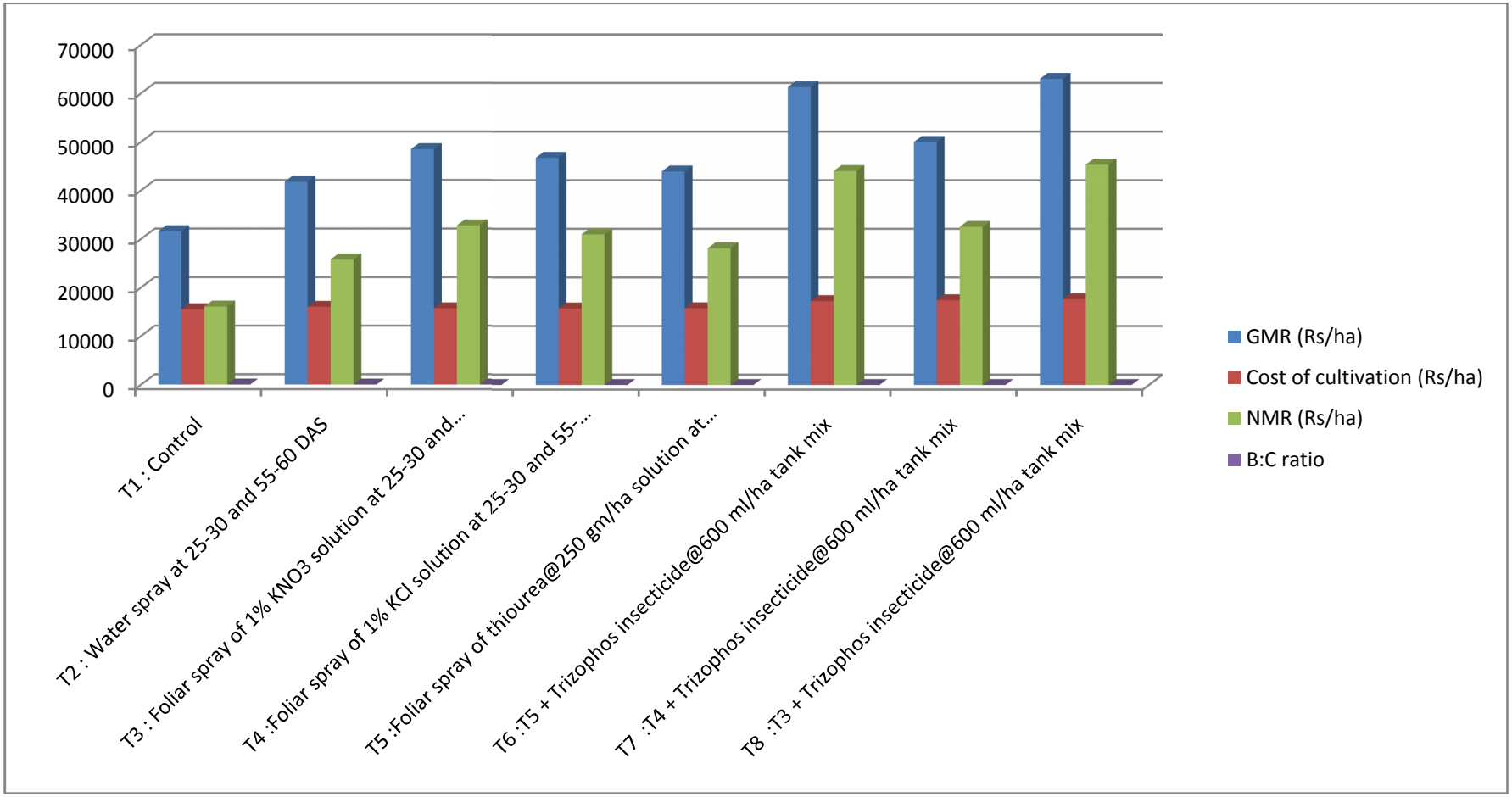

Fig.10: Gross and net returns of soybean as influenced by foliar spray of chemicals for mitigating drought effect.

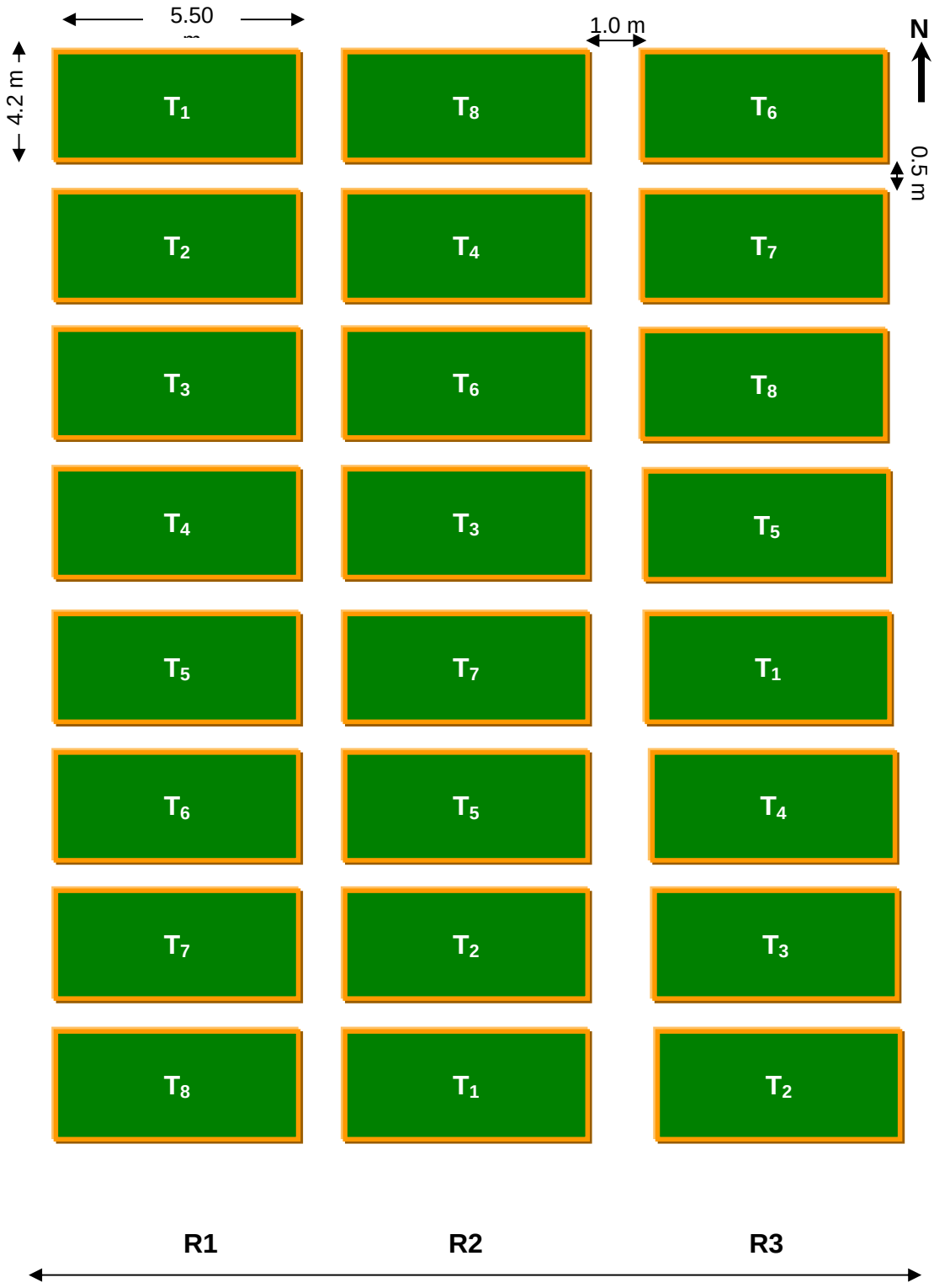

Fig. 2. Layout plan of the experiment

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APPENDICES

Appendix I: Common cost of cultivation per hectare area basis

S.No.	Particulars	Input (ha^{-1})	Cost /Unit (Rs)	Cost ($Rsha^{-1}$)
A	Land preparation			
I	Harrowing with Cultivator	Two pass	800/pass	1600
II	Harrowing with Disc harrow	Two pass	800/pass	1600
III	Leveling	One pass	200/pass	200
IV	Drainage channel	One pass	500/pass	500
B	Seed and sowing			
	Cost of seed	75 kg	60/kg	4500
I	Seed treatment	200 g	200/kg	40
II	Seed inoculation	500 g	75/kg	38
III	Treatment and inoculation charges	1 man Day	200	200
IV	Cost of sowing		750	750
C	Fertilizers			
I	Cost of fertilizers	20 kg N	16/kg	320
		40 kg P	23.25/kg	930
II	Application charges	man days	200	200
III	Land revenue			50
IV	10% interest of fix cost			1087.8
	Total			12015.8

Appendix II: Variable cost of treatment

Treatments	Dose (ml or kg ha^{-1})	Unit price (Rs/litre or kg)	Cost (Rs ha^{-1}) including application charges	Common cost (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})
T_1	0	0	0	12015.8	15515.8
T_2	0	0	0	12015.8	16015.8
T_3	1kg	100	100	12015.8	15715.8
T_4	1kg	90	90	12015.8	15755.8
T_5	1kg	80	80	12015.8	15795.8
T_6	1kg+600 ml ha^{-1}	100+1250	1350	12015.8	17265.8
T_7	1kg+600 ml ha^{-1}	90+1250	1340	12015.8	17455.8
T_8	1kg+600 ml ha^{-1}	80+1250	1330	12015.8	17645.8

Appendix III: Economics of treatments

Treatment	Seed yield kg ha^{-1}	Seeds Rs ha^{-1}	Straw yield	Straw Rs ha^{-1}	Cost of cultivation (Rs ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C ratio
T_1	679.65	29225.10	2371.12	2371.121	15515.80	31596.23	16080.43	2.04
T_2	904.76	38904.76	2876.57	2876.571	16015.80	41781.33	25765.53	2.61
T_3	1049.06	45109.66	3390.39	3390.387	15715.80	48500.05	32784.25	3.09
T_4	1018.76	43806.63	2932.23	2932.225	15755.80	46738.86	30983.06	2.97
T_5	952.38	40952.38	2975.91	2975.908	15795.80	43928.29	28132.49	2.78
T_6	1356.42	58326.11	2953.96	2953.958	17265.80	61280.08	44014.28	3.55
T_7	1089.47	46847.04	3145.85	3145.853	17455.80	49992.89	32537.09	2.86
T_8	1390.94	59810.58	3170.22	3170.222	17645.80	62980.80	45335.00	3.57

Appendix IV: Mean sum of square

A)

Mean sum of square							
		Plant population		Plant height (cm)			
SV	df						
		20 DAS	at harvest	20 DAS	40 DAS	60 DAS	at harvest
Rep	2	7.17	3.45	1.16	5.68	10.99	19.13
Trt	7	1.40	1.23	2.89*	12.03*	24.10*	24.11*
Error	14	2.26	1.41	0.93	2.25	3.76	6.23
Total	23	2.43	1.53	1.55	5.52	10.58	12.79

*** 5% level of significant**

B)

Mean sum of square							
		Number of leaves plant^{-1}			Number of branches plant^{-1}		
SV	df						
		20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Rep	2	0.39	3.55	2.87	0.17	0.13	0.07
Trt	7	1.23*	6.82*	7.02*	0.16*	0.16*	0.17*
Error	14	0.42	1.40	0.77	0.05	0.05	0.05
Total	23	0.66	3.24	2.86	0.09	0.09	0.09

*** 5% level of significant**

C)

Mean sum of square				
SV	**df**	**No. of pod plant^{-1}**	**No. of seeds pod^{-1}**	**No. of seeds plant^{-1}**
Rep	2	5.71	0.08	12.98
Trt	7	53.41*	0.25*	1131.66*
Error	14	6.77	0.05	10.39
Total	23	20.87	0.11	351.87

*** 5% level of significant**

D)

Mean sum of square				
SV	**df**	**Seed yield (kg ha^{-1})**	**Straw yield (kg ha^{-1})**	**Harvest index (%)**
Rep	2	107.58	857.02	0.21
Trt	7	162958.44*	264191.40*	32.86*
Error	14	197.12	900.18	0.63
Total	23	49725.39	81028.53	10.40

*** 5% level of significant**

“Studies on mitigation of drought effect through foliar spray of chemicals on soybean (Glycine max L. Merril) under rainfed condition.”

THESIS ABSTRACT

Submitted to the

Jawaharlal Nehru Krishi Vishwa idyalaya, Jabalpur

In partial fulfillment of the requirement
For the Degree of

MASTER OF SCIENCE

In

AGRICULTURE

(AGRONOMY)

By

JITENDRA MARSKOLE

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE, REWA

JAWAHARLAL NEHRU KRISHI VISHWA VIDYALAYA JABALPUR,

MADHYA PRADESH

2016

ABSTRACT Part-I

Title of the thesis	**:**	**"Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition*."***
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Degree awarded	**:**	M.Sc. (Ag.) Agronomy
Year of award of Degree	**:**	2016
Major Subject	**:**	Agronomy
Total number of pages in the thesis	**:**	50
Number of words in the abstract	**:**	766

Dr. V.D. Dwivedi **Dr. D.P. Dubey** **Mr. Jitendra Marskole**

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ABSTRACT PART-II

Soybean (*Glycine max* L. Merril**)** is one of the commercial crops in India. Soybean is a crop of multiple qualities, as it is both a pulse and oilseed crop. It contains 40 percent protein and 20 percent edible oil, besides minerals and vitamins. As per survey conducted by SOPA, the all India estimated production 12.98 million tonnes from an area of 12.03 million hectare with productivity of 1079 kg/ha. In Madhya Pradesh the area under soybean cultivation is 6.26 million hectares with the production of 5.95 million tonnes**.** Although the ecological conditions of the state are congenial for soybean production, but the yield is substantially low (950 kg/ha), despite of the best management practices (SOPA, 2014). A field experiment was conducted during kharif season of 2015, AICRP for Dryland Agriculture, Kuthulia Farm College of Agriculture, Rewa (M.P.) to study the "Studies on mitigation of drought effect through foliar spray of chemicals on soybean (*Glycine max* L. Merril) under rainfed condition*."* Keeping above facts in view, present study has been taken with following objectives to assess the growth and development of soybean as influence by different chemicals spray. To find out the suitable chemical to mitigate drought in soybean. To judge the comparative performance of different chemicals and water spray from control on the basis of economics of treatments.

The present experiment was carried out on clayey soil which was medium in organic carbon (0.60 %), available nitrogen (350 kg/ha) and phosphorus (16.50 kg/ha) but high in potassium (333 kg/ha) and neutral in reaction (7.1). The investigation was aimed to study the efficacy of drought effect through foliar spray of chemicals and to determine economic viability of treatments. Eight treatments comprised of water spray,1% KNO_3, 1% KCl, thiourea@250g/ha and their combination with trizophos at 25-30 and 55-60 DAS and control plots were laid out in Randomized Block Design with three replications. All foliar spray chemicals treatments were applied in 500 liters of water per hectare, using flat fan nozzle. Different observations on the crop

parameters were carried out during the course of investigation. Plant population of soybean was recorded at 20 DAS and harvest. Growth parameters viz., plant height (cm), number of branches per plant, number of leaf were recorded at different time intervals. Yield attributing traits viz., pods per plant, seeds per pod and seed index (100 seed weight) were recorded at maturity. Finally, seed and straw yields were recorded treatment wise. Tabulation and statistical analysis of data were done for testing the significance among the different treatments which are summarized below.

The plant population of soybean was not affected under all treatments at 20 DAS and at harvest, indicating that these treatments did not adversely affect the germination and further survival of crop plants. Consequently, plant population was almost similar under all treatments. Growth parameters like plant height, branches per plant, number of leaves per plant were significantly superior in treated plot than control plots. However, foliar spray treatment was better overall treatments closely followed by T_3. Yield attributing traits viz., pods per plant and seed index (100 seed weight) were also superior under treated plots as compared to control plots in which these parameters were inferior. Both seed and straw yields were significantly higher under all the treatments receiving foliar spray measure than control plots. Maximum seed yield of soybean was recorded under T_8 treatment and proved superior over all the treatments except foliar spray 1% KNO_3 + Trizophos@600g/ha (T_8) which was found significantly superior over all the treatment. Foliar spray chemical treatments received T_8 maximum investment (Rs 17645.80 /ha) to control weeds, while expenditure incurred under treatment (T_2) water, (T_3) 1% KNO_3, (T_4) 1% KCl, (T_5) thiourea@250g/ha and (T_6), (T_7) and (T_8) combination with trizophos at 25-30 and 55-60 DAS ranged from Rs 15515.80/ha to Rs 17645.80/ha, maximum gross monetary return (Rs 62980.80/ha) was obtained under foliar spray treatment closely followed by T_8 1% KNO_3 + Trizophos@600g/ha. Though GMR was maximum in foliar spray treatments, but the net monetary returns and B:C ratio were also the

highest under 1% KNO_3 + Trizophos@600g/ha (T_8) closely followed by (T_6) thiourea@250g + Trizophos@600g/ha to soybean. Based on the foregoing discussion, the following conclusions could be drawn. Growth and development was better in T_8 (foliar spray of 1% KNO_3+ trizophos@600ml/ha). The foliar spray of Thiourea@250g/ha and 1% KNO_3 is the suitable chemical to mitigating drought in soybean. The grain yield (1390.94 kg/ha), net returns Rs45335/ha and B:C ratio 3.57 were maximum number foliar spray of 1% KNO_3 at 25-30 and 55-60 DAS + Trizophos@600ml/ha tank mix compared to other treatments.