LR-5263
[1-7]

RESEARCH ARTICLE Legume Research- An International Journal

Alleviation of Drought Stress in Soybean [*Glycine max* (L.) Merril] by Foliar Application of Thiourea on Productivity and Profitability under Rainfed Condition

G. Somanagouda[1], R. Channakeshava[1], Shalini N. Huilgol[1], G.K. Naidu[1], Harshiya Banu[1] 10.18805/LR-5263

ABSTRACT

Background: In changing climatic scenario, plants often face periods of soil and atmospheric water deficits because of scarcity of water availability and deteriorating quality across the globe. Drought stress is the one of the major abiotic factors that reduce plant water status, obstructs photosynthesis, brings oxidative stress hindering soybean productivity. In view of this, bioregulators (thiourea) are innovative agricultural technique used to protect plants, minimizing the adverse effects caused by environmental stress. Therefore, an alternative to improve crop yield under rainfed condition by application of bioregulators like thiourea and suitable varieties are important in order to mitigate stress in soybean production.

Methods: The field experiments were conducted in Factorial RBD with three replications. To know the impact of foliar spray of thiourea on growth, physiological parameters, yield parameters, yield and economics of two soybean varieties were carried out during *kharif* 2020, 2021 and 2022.

Result: Long term results showed that, by using MACS 1188 variety of soybean and foliar spray of thiourea at 500 ppm and 750 ppm during the 25 and 55 DAS is a commendatory option and most remunerative for farmers to improve the productivity and profitability of soybean in Northern Transition Zone of Karnataka.

Key words: Drought, Productivity, Profitability, Soybean, Thiourea.

INTRODUCTION

Drought is a critical environmental factor that imposes water stress on crops and a major constraint on plant growth and productivity (Rampino *et al.,* 2006). It is the most damaging abiotic stress affecting modern agriculture (Zhang *et al.,* 2006). Scarcity of water may become more severe in the future with changing global climate. A lack of sufficient moisture leading to drought stress is a common phenomenon in rainfed areas, brought about by uneven and erratic rain and poor irrigation (Wang *et al.,* 2005). Drought hinders the global production of soybean (*Glycine max* L. (Merril), which provides 71 per cent and 29 per cent of the world's protein and oil consumption, respectively (Wijewardana *et al.,* 2019).

In India average productivity of soybean is low due to sink limited nature, flower drop, poor adoption of improved technology, soil moisture stress, high temperature stress, erratic rainfall and biotic stresses like pests and diseases (Engels *et al.,* 2017). To address these constraints, several measures can be taken, such as ensuring the supply of good quality seeds, dealing with biotic stresses through resistant varieties of soybean like JS-93-05 and MACS 1188. Economic yield reduction due to drought stress at various growth stages has been reported in many field crops such as, soybean (Samarah *et al.,* 2006) and maize (Monneveux *et al.,* 2006). However, to meet the growing demand for food, it is necessary to increase soybean yield, even in environments with low water availability (Rosa *et al.,* 2021).

The productivity of soybean in India is quite low and it faces several constraints related to its physiology, management and external stresses. Some of the notable reasons for the low productivity of soybean include sink limited nature, leaf fall, flower drop, poor availability of quality inputs, poor adoption of improved technology, soil moisture stress, high temperature stress, erratic rainfall and biotic stresses like pests and diseases. Out of all the environmental stresses that soybean crop faces, it is believed that irregular rainfall is the main cause of yield reductions (Engels *et al.,* 2017). Drought stress causes a decrease in the soybean plant's leaf area index, chlorophyll content and relative water content. Additionally, it results in an increase in the level of osmolytes in the plant (Dong *et al.,* 2019).

To address these constraints, several measures can be taken, such as ensuring the supply of good quality seeds,

[1]All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India.

Corresponding Author: G. Somanagouda, All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India. Email: sgouda111@gmail.com

How to cite this article: Somanagouda, G., Channakeshava, R., Huilgol, S.N., Naidu, G.K. and Banu, H. (2024). Alleviation of Drought Stress in Soybean [*Glycine max* (L.) Merril] by Foliar Application of Thiourea on Productivity and Profitability under Rainfed Condition. Legume Research. DOI: 10.18805/LR-5263.

Submitted: 25-10-2024 **Accepted:** 11-07-2024 **Online**: 30-07-2024

dealing with biotic stresses through resistant varieties of soybean and improving abiotic stress and nutrient management through the use of bioregulators like thiourea. Thiourea, an organosulfur compound, is a well-known bio-regulator for plants that can help mitigate abiotic stresses and improve the nutrient management system in soybean cultivation (Makadia, 2018). Thiourea has been shown to enhance the plant's defense against fungal and bacterial diseases. It can activate various defense mechanisms such as lignification, production of phytoalexins and strengthening of the cell wall, which ultimately reduces the severity of the disease. Thiourea can help alleviate abiotic stress such as drought, salinity and heavy metal toxicity (Srivastava *et al.,* 2017). It has been shown to improve plant growth and photosynthesis under stress conditions. In view of this, bioregulators (thiourea) are innovative agricultural techniques used to protect plants, minimizing the adverse effects caused by environmental stress (Abhishek *et al.,* 2021). Therefore, an alternative to improve crop yield under rainfed condition by application of bioregulators like thiourea is/are important in order to mitigate stress in soybean production.

Thiourea is an analogue of urea which provides sulphur (42% S) in addition to the nitrogen (36% N) and helps the crop to alleviate the damage caused by several biotic and abiotic stresses. Exogenous application of thiourea also stimulates defense mechanisms under abiotic stress. It helps to reduce the accumulation of reactive oxygen species (ROS) and also increases the activity of antioxidant enzymes, which ultimately leads to improved

Table 1: Details of experimental site and crop management practices.

Site characteristic and crop management practices during cropping period	
Agroclimatic Zone	Northern Transition Zone (VIII)
State and District	Karnataka and Dharwad
Coordinates of the site	15.4461072 Latitude and 74.9986732 Longitude
Mean annual rainfall (mm)	838.0 mm
Major soil type	Black cotton soil (*Vertisol*)
Available nutrient status (kg ha^{-1})	N-197, P_2O_5-26 and K_2O-301
Major crops grown	Maize, Wheat, Cotton, Soybean, Chickpea
Growing period temperature (°C)	June (29.4, 28.3 and 29.9) July (27.5, 27.2 and 26.6), August (26.1, 28.0 and 27.4), September (28.4, 28.0 and 28.7) months (Fig 1)
Date of sowing	19.06.2020, 23.06.2021 and 12.06.2022
Nutrient management (kg ha^{-1})	FYM-6000, N-40, P_2O_5-80, K_2O-25 and S-20
Weed management practices	Alachlor 50 EC @ 4ml/L : Pre-emergentIntercultivation: 25 DASHand Weeding: 40 DAS
Irrigation	Nil
Insect control	Lambda cyhalothrin 5% EC : 0.5 ml/Land Chlorantraniliprole 18.5% SC : 0.2 ml/L

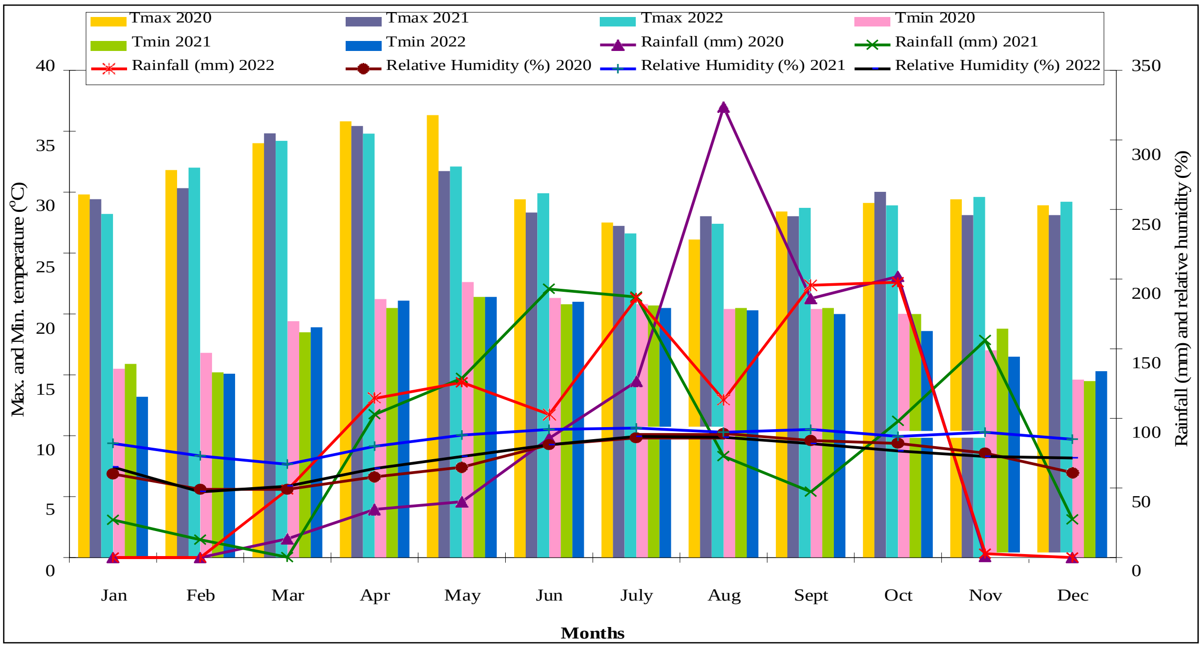

Fig 1: Mean monthly meteorological data of experimental site during 2020, 2021 and 2022.

plant tolerance to abiotic stress (Hassanein *et al.,* 2015). Further, at physiological level, this is directly associated with enhanced photosynthesis, increased metabolite translocation and co-ordinated regulation of plant's source to sink relationships and also higher productivity (Pandey *et al.,* 2013).

Taking all these above factors into account, the current study was conducted over three years to assess how various concentrations of foliar spray of thiourea, applied at various phases of crop growth, would impact on growth, physiological parameters, yield parameters and economics in two soybean varieties under rainfed conditions.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted during the *kharif* season of 2020, 2021 and 2022 at AICRP on Soybean, MARS, University of Agricultural Sciences, Dharwad under rainfed conditions. The details of experimental site characteristic and crop management practices (Table 1) and meteorological data of study area is presented in Fig 1.

Experimental design and treatment details

The experiment involved two varieties of soybean and five different foliar sprays (control, water spray and three concentrations of thiourea which were arranged using a factorial randomized block design. The two varieties (Factor A) used were V_1-JS 93-05 and V_2-MACS 1188. While the five foliar sprays (Factor-B) were control (F_1), water spray (F_2), thiourea at 250 ppm (F_3), thiourea at 500 ppm (F_4) and thiourea at 750 ppm (F_5). Water or thiourea foliar spray was conducted at varying concentrations during 25 and 55 days after sowing of crop.

Collection of data on growth, yield and its components of soybean

Crop was raised with recommended package of practices. Observations were recorded on plant height, number of branches, dry matter production, number of pods per plant and test weight. Grain and straw yield was calculated based on the yield obtained from each net plot and converted into to kg ha^{-1}. For the estimation of LAI, the leaves of the selected plants were detached at 60 DAS after removal from the plot, area of the leaves were calculated by placing it on levelled land and by using meter tape. Following formula, given by Watson (1947), was utilized for calculation of LAI:

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area per plant}}{\text{Land area per plant}}$$

Representative samples are also utilized to measure the PAR and chlorophyll content. Chlorophyll content was measured by using SPAD-502 by punching the leaves in the SPAD meter. PAR was measured by using a crop analyser. The difference between incident solar radiation and transmitted solar radiation is recorded as intercepted solar radiation.

Calculation of (Relative water content) RWC (%) of leaves according to the formula given by Weatherley, (1950):

$$\text{RWC (\%)} = \frac{\text{Fresh weight-Dry weight}}{\text{Turgid weight-Dry weight}} \times 100$$

Statistical analysis

The statistical analysis of data on various recorded parameters of growth, yield, physiological parameters and economics was done by using Factorial randomized block design as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on growth attributes of soybean

Pooled data presented in Table 2, reveled that, use of two different varieties and the foliar spray of thiourea resulted in significant variation in growth parameters. Among the varieties, MACS 1188 recorded significantly higher plant height (69.39 cm), number of branches per plant (5.73) and total dry matter production (68.39 g plant^{-1}) as compared to JS 93-05 (51.05 cm, 5.28 and 54.52 g plant^{-1}, respectively) at 60 DAS (Table 2).

Among the foliar spray, thiourea @ 750 ppm at 25 and 55 DAS recorded significantly higher plant height (66.09 cm), number of branches per plant (6.01) and total dry matter production (65.97 g plant^{-1}). However, it was on par with thiourea @ 500 ppm. Significantly the lowest growth attributes were recorded in control (55.60 cm, 5.02 and 55.03 g plant^{-1}) respectively) at 60 DAS (Table 2). But interaction of varieties and foliar spray of thiourea could not bring any significant variation. Similar findings were also obtained by (Meena and Bhati 2016) and (Premaradhya *et al.,* 2018).

The increase in various growth parameters can be attributed due to the presence of two macronutrients in thiourea (Nitrogen and Sulphur). Nitrogen improves the activity of growth-promoting hormone, which leads to better cell division and growth (Meena *et al.,* 2023). In addition to that, Sulphur aids to the formation of protein which is the building block of living organisms (Jhanji and Dhingra, 2018). Further Better photosynthetic ability and partitioning of photosynthates in variety MACS 1188 resulted in higher dry matter production. An increment in dry matter production due to foliar spray of thiourea is related to the improvement in plant height, better interception of PAR and mainly due to the improvement in growth influencing parameters and processes. The enzyme and protein stabilising nature of thiourea and its ability to increase the activity of nitrate reductase activity also contributed to the increase in dry matter of the crop (Anitha *et al.* 2006) and (Sachin *et al.,* 2019).

Physiological parameters of soybean

Among the varieties, MACS 1188 recorded significantly higher LAI (3.22), PAR (1060.4), chlorophyll content (39.8%)

Table 2: Effect of different treatments on growth parameters and physiological parameters of soybean (Data pooled over 3 years).

Treatments	At 60 DAS			Physiological parameters at 60 DAS			
	Plant height (cm)	Number of branches per plant	Total dry matter production (g plant^{-1})	LAI	PAR (µmol/m^2/s)	Chlorophyll content (%)	Relative water content (%)
Factor A (Variety)							
V1-JS 93-05	51.05	5.28	54.52	3.22	1010.2	36.4	75.5
V2- MACS 1188	69.39	5.73	68.39	2.96	1060.4	39.8	82.4
S.Em±	0.74	0.10	0.74	0.03	16.2	0.58	0.85
C.D at 5%	2.19	0.29	2.20	0.14	45.6	1.5	2.34
Factor B (Foliar Spray)							
F1-Control	55.60	5.02	55.03	2.56	974.5	34.2	65.7
F2-Water spray at 25 and 55 DAS	60.17	5.16	60.83	2.80	967.1	35.6	68.5
F3-Thiourea @ 250 ppm at 25 and 55 DAS	58.45	5.58	62.92	2.89	1035.2	36.8	71.2
F4-Thiourea @ 500 ppm at 25 and 55 DAS	60.81	5.74	62.56	3.12	1098.5	40.4	75.5
F5-Thiourea @ 750 ppm at 25 and 55 DAS	66.09	6.01	65.97	3.28	1124.6	42.58	78.4
S.Em±	1.16	0.15	1.17	0.07	25.5	0.94	1.25
C.D at 5%	3.46	0.46	3.48	0.21	78.4	2.4	3.58

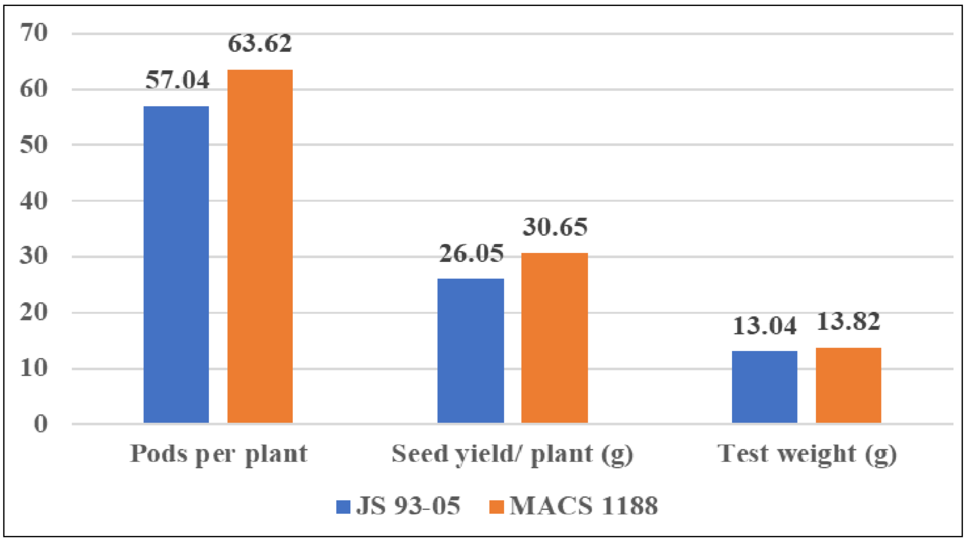

Fig 2: Effect of varieties on yield attributes of soybean.

and RWC (82.4%) as compared to JS 93-05 (2.96, 1010.2 µmol/m^2/s, 36.4 % and 75.5% respectively) at 60 DAS on pooled basis (Table 2). Foliar spray of thiourea @ 750 ppm at 25 and 55 DAS recorded significantly higher LAI (3.28), PAR (1124.6 µ mol/m^2/s), chlorophyll content (42.58%) and RWC (78.4%). However, it was on par with thiourea @ 500 ppm. Significantly the lowest physiological parameters were recorded in control (2.56, 974.5 µmol/m^2/s and 34.2% and 65.7% respectively) at 60 DAS (Table 2). But interaction of varieties and foliar spray of thiourea could not bring any significant variation.

The foliar spray of thiourea, helps maintain turgor pressure in cells and might result in increased LAI (Meena *et al.,* 2023; Verma, 2019). Further directly provides nutrients to the growing part of the crop which ultimately better absorption of nutrients and then the formation of chlorophyll in the plant system is positively influenced. The similar results were collaborated with the findings of Amanmmula *et al.* (2014) also observed that water-soluble fertilizer significantly increased the PAR interception and chlorophyll content. Increased intercepted PAR and chlorophyll content will eventually result in an increased net photosynthetic rate and, thus, better yield. Apart from that, the foliar application of thiourea is also known to regulate several key steps of photosynthesis (Pandey *et al.,* 2013) and (Choudhary *et al.,* 2017). Further, leaf relative water content (RWC) is an important indicator of water status in plants; it reflects the balance between water supply to the leaf tissue and transpiration rate (Lugojan and Ciulca, 2011).

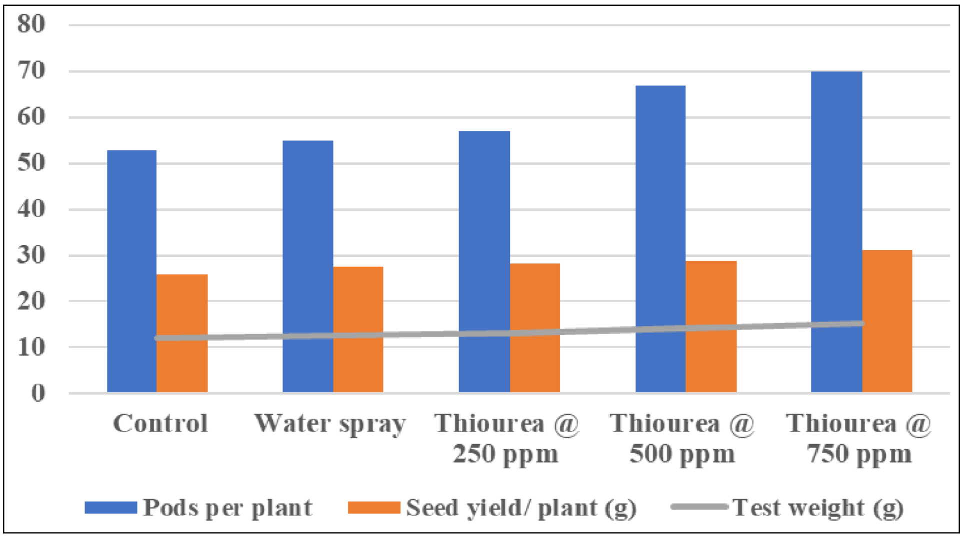

Fig 3: Effect of foliar spray on yield attributes of soybean.

Table 3: Effect of different treatments on yield and economics of soybean (Data pooled over 3 years).

Treatments	Yield (kg ha^{-1})			Economics (Rs. ha^{-1})		
	Seed yield	Straw yield	Biological yield	Gross returns	Net returns	BC ratio
Factor A (Variety)						
V1-JS 93-05	2236	3432	5668	121823	83537	3.2
V2- MACS 1188	2726	3912	6638	148528	109933	3.8
S.Em±	35.2	47.3	70.2	1885	1885	0.0
C.D at 5 %	103.1	140.1	208.8	5601	5601	0.1
Factor B (Foliar Spray)						
F1-Control	2250	3346	5596	122590	85828	3.3
F2-Water spray at 25 and 55 DAS	2357	3491	5847	128397	90797	3.4
F3-Thiourea @ 250 ppm at 25 and 55 DAS	2453	3662	6114	133644	95250	3.5
F4-Thiourea @ 500 ppm at 25 and 55 DAS	2629	3855	6485	143268	104148	3.7
F5-Thiourea @ 750 ppm at 25 and 55 DAS	2716	4008	6724	147980	107652	3.7
S.Em±	55.2	74.5	111.3	2980	2980	0.08
C.D at 5 %	162.6	221.2	329.1	8855	8855	0.23

Yield attributes and yield of soybean

Significantly higher yield attributes *viz.,* number of pods per plant (63.62), seed yield per plant (30.65 g) and test weight (13.82 g), seed yield (2726 kg ha^{-1}), straw yield (3912 kg ha^{-1}) and biological yield (6638 kg ha^{-1}) was recorded in variety of MACS 1188 than JS 93-05 on pooled basis (Fig 2 and Table 3).

Pooled data presented in Fig 3 and Table 3, reveled that, foliar spray of thiourea @ 750 ppm at 25 and 55 DAS recorded significantly higher yield parameters *viz.,* number of pods per plant (69.83), seed yield per plant (31.28 g) and test weight (15.24 g) and seed, straw and biological yield (2716, 4008 and 6724 kg ha^{-1}, respectively) followed by thiourea @ 500 pm. Whereas, significantly lowest yield attributes (52.91, 25.97 g and 12.03 g respectively) and yields (2250, 3346 and 5596 kg ha^{-1}) respectively). The application of thiourea through foliar spray at 500 and 750 ppm rates led to a significant improvement in the seed yield of soybean crop, with increases of 14.41 and 17.15 per cent respectively, when compared to the control.

Foliar application of thiourea directly provides nutrients to the growing part of the crop. It ultimately results in higher photosynthetic activity, better absorption of nutrients and then the formation of chlorophyll in the plant system and improved functioning of several chloroplastic enzymes under the influence of nitrogen and sulphur present in it. Sulphur present in thiourea also protected the plants from several abiotic and oxidative stresses which led to better functioning of the plants under normal or stress conditions (Meena *et al.,* 2016). Increase in number of branches per plant, total dry matter production and number of pods per plant *etc.,* ultimately led to the improvement in yield of the soybean crop. The similar results were obtained by Anitha *et al.,* (2004) and Bangar *et al.,* (2019) and Meena *et al.,* (2023).

Economics

The higher gross, net returns and benefit cost ratio (Rs. 1,48,528 ha^{-1}, 1,09,933 ha^{-1} and 3.8, respectively) were observed in variety MACS 1188 than variety JS 93-05 on pooled basis (Table 3). Among the foliar spray, significantly highest gross (Rs. 1,47,980 ha^{-1}) net returns (1,07,652 ha^{-1}) and B:C (3.7) was observed with thiourea @ 750 ppm, which was equally effective as the application at 500 ppm. Both of these treatments showed better results than the control, water spray and thiourea @ 250 ppm. The higher returns in thiourea application which directly related to the yields. This finding is consistent with a similar study by Bangar *et al.* (2019) and Meena *et al.* (2023).

CONCLUSION

From the results of experiment (3 years data) it was determined that MACS 1188 variety of soybean produced higher growth, yield and economic returns compared to JS 93-05 variety. The application of thiourea through foliar spray at 500 and 750 ppm led to a significant improvement in the seed yield of soybean crop, with extent of 14.41 and 17.15 per cent respectively, when compared to the control. Therefore, it can be concluded that by using MACS 1188 variety of soybean and foliar spray of thiourea at 500 ppm and 750 ppm at 25 and 55 DAS is a commendatory option and most remunerative for farmers to improve the productivity and profitability of soybean in Northern Transition Zone of Karnataka.

ACKNOWLEDGEMENT

Authors are grateful to University of Agricultural Sciences, Dharwad (Karnataka) and Indian Institute of Soybean Research, Indore for providing facilities in smooth conduct of the experiment.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Abhishek, Doddagoudar S.R., Basavegowda, Shakuntala N.M., Meena M.K. (2021). Mitigation of moisture stress through foliar spray of thiourea, salicylic acid and homobrassinolide in chickpea (*Cicer arietinum* L.). Legume Research. 44(9): 1032-1037. doi: 10.18805/LR-4206.

Amanmmula, D., Sinha, K.K., Sharma, R.P. (2014). Effect of organic manure, NPK and boron application on the productivity of wheat in sandy loam soil of North Bihar. Indian Journal of Pulses Research. 17: 42-44.

Anitha, S., Purushothaman, S.M., Sreenivasan, E. (2006). Response of horse gram [*Macrotyloma uniflorum* (Lam.) Verdc] to thiourea under rainfed conditions. Legume Research-An International Journal. 29: 146-149.

Anitha, S., Sreenivasan, E., Purushothaman, S.M. (2004). Effect of thiourea application on cowpea [*Vigna unguiculata* (L.) Walp.] productivity under rainfed condition. Journal of Tropical Agriculture. 42: 53-54.

Bangar, K.D., Shinde, R.S., Suryavanshi, V.P., Bhutada, P.O. (2019). Effect of foliar application of agrochemicals on growth, yield and economics of soybean [*Glycine max* (L.) Merrill]. Journal of Pharmacognosy and Phytochemistry. 2: 44-46.

Choudhary, S., Sharma, O.P., Choudhary, G.L., Jat, L. (2017). Response of urdbean [*Vigna mungo* (L.) Hepper] to phosphorus fertilization and thiourea on yield, quality, nutrient content and uptake. International Journal of Current Microbiology and Applied Science. 6: 2841-2847.

Dong, S., Jiang, Y., Dong, Y., Wang, W., Ma, Z., Yan, C., Ma, C., Wang, L. (2019). A study on soybean plant to drought stress and rehydration. Saudi Journal of Biological Sciences. 26: 2006-2017.

Engels, C., Rodrigues, F., Ferreira, A.D.O., Inagaki, T.M., Nepomuceno, A. (2017). Drought effect on soybean cultivation-A Review. Annual Research. Review Biology. 16: 1-13.

Gomez, K.A., Gomez, A.A. (1984). Statistical Procedures for Agricultural Research with Emphasis on Rice. John Wiley and Sons, New York. pp. 680.

Hassanein, R.A., Amin, A.A.E., Rashad, E.M., Ali, H. (2015). Effect of thiourea and salicylic acid on antioxidant defense of wheat plant under drought stress. International Journal of Chemtech Research. 7: 346-354.

Jhanji, S., Dhingra, M. (2018). Ameliorative effect of thiourea priming on germination characteristics of mungbean (*Vigna radiata* L.) under water and salinity stress. Legume Research. 43: 353-358.

Lugojan, C., Ciulca, S. (2011). Evaluation of relative water content in winter wheat. Journal of Horticulture and Forestry Biotechnology. 15: 173-177.

Makadia, M.B. (2018). Efficacy of thiourea application on biochemical changes in chickpea under water stress condition. M.Sc. Thesis, JAU, Junagadh. http://krishikosh.egranth.ac.in/handle/1/5810064644.

Meena V.K., Kaushik M.K., Kumar, R., Meena, B.L., Meena, B.P., Kumar, R., Kumar U., Kumar, S. (2016). Influence of growth regulators on nutrient concentrations, nutrient uptake and quality parameters of cluster bean varieties. Legume Research. 39(5): 797-801. doi: 10.18805/lr.v0iOF.3764.

Meena, D.K., Sharma, R.K., Kumar, A, Bhatnagar, A., Dawar, R., Glotra, A., Kumar, S., Singh, T. (2023). Impact of foliar spray of thiourea on growth attributes of two cultivars of soybean. Journal of Agriculture and Ecology. 15: 134-139.

Meena, N.K., Bhati, A. (2016). Response of nitrogen, phosphorous and potassium levels on growth and yield of okra [*Abelmoschus esculentus* (L.) Moench.]. Journal of Agriculture and Ecology. 2: 17-24.

Monneveux, P., Sanchez, C., Beck, Edmeades, G.O. (2006). Drought tolerance improvement in tropical maize source populations: Evidence of progress. Crop Science. 46: 180-191.

Pandey, M, Srivastava, A.K, D'Souza, S.F., Penna, S. (2013). Thiourea, a ROS scavenger, regulates source-to-sink relationship to enhance crop yield and oil content in *Brassica juncea* (L.). PLoS ONE. 8: e73921.

Premaradhya, N. Shashidhar, K.S, Jeberson, S, Krishnappa, R., Singh, N. (2018). Effect and profitability of foliar application of thiourea on growth and yield attributes of lentil (*Lens culinaris* L.) under Manipur conditions of North-East India. International Journal of Current Microbiology and Applied Sciences. 7: 1040-1050.

Rampino, P., Pataleo, S., Gerardi, C., Mita, G., Perrotta, C. (2006). Drought stress response in wheat: physiological and molecular analysis of resistant and sensitive genotypes. Plant Cell Environment. 29: 2143-2152.

Rosa, V.D., Santos, A.L., Silva, A.A., Sab, M.B., Germino G., Silva, M.D. (2021). Increased soybean tolerance to water deficiency through biostimulant based on fulvic acids and *Ascophyllum nodosum* (L.) seaweed extract. Plant physiology and Biochemistry. 158: 228-243.

Sachin, A.S., Sivakumar, T., Krishna Surendar K., Senthivelu, M. (2019). Influence of plant growth regulators and nutrients on biometric, growth and yield attributes in Blackgram (*Vigna mungo* L.). Journal of Agriculture and Ecology. 7: 55-63.

Samarah, N.H., Mullen, R.E., Cianzio, S.R., Scott, P. (2006). Dehydrin-like proteins in soybean seeds in response to drought stress during seed filling. Crop Science. 46: 2141-2150.

Srivastava, A.K., Sablok ,G., Hackenberg, M., Deshpande, U., Suprasanna, P. (2017). Thiourea priming enhances salt tolerance through co-ordinated regulation of microRNAs and hormones in *Brassica juncea*. Scientific Reports. 7: 45490|doi: 10. 1038/srep45490.

Verma, C.B. (2019). Physiological traits and productivity of wheat (*Triticum aestivum* l.) in relation to foliar spray of zinc, urea and thiourea under rainfed condition. Agricultural Science Digest. 39(2): 124-127. doi: 10.18805/ag.A-4458.

Wang, F.Z., Wang, Q.B., Kwon, S.Y., Kwak, S.S., Su, W.A. (2005). Enhance drought tolerance of transgenic rice plants expressing a pea manganese superoxide dismutase. Journal of Plant Physiology. 162: 465-472.

Watson, D. (1947). Comparative physiological studies in the growth of field crops I: Variation in net assimilation rate and leaf area index between species and varieties within and between years. Annals of Botany. 11: 41-76.

Weatherley, P.E. (1950). Studies on the water relations of the cotton plant, the field measurement of water deficit in leaves. New Phytologist. 40: 81-97.

Wijewardana, C., Reddy, K.R., Krutz, L.J. Gao, W., Bellaloui, N. (2019). Drought stress has transgenerational effects on soybean seed germination and seedling vigor. PLoS ONE. 14:e0214977.

Zhang, J., Jia, W., Yang, J., Ismail, A.M. (2006). Role of ABA in integrating plant responses to drought and salt stresses. Field Crops Research. 97: 111-119.