



Impact of foliar spray of thiourea on growth attributes of two cultivars of soybean

DK Meena^{a#}, RK Sharma^b, A Kumar^b, A Bhatnagar^b, R Dawar^a, A Glotra^a, S Kumar^a and T Singh^a

Summary

Soybean is one of the major oilseed crops cultivated in India and globally. In India, it is mainly cultivated in Madhya Pradesh, Rajasthan, Karnataka and Telangana. Despite being grown in large areas, the importance of soybean and its oil is still very prevalent. The objective was to investigate the impact of foliar spraying of thiourea at three different concentrations (250, 500, and 750 ppm) during two growth stages (20-25 days after sowing and 50-55 days after sowing) on two soybean varieties, PS1347 and SL958. Several growth parameters were recorded and then analysed, such as plant height, plant dry weight, stem girth, leaf chlorophyll content, intercepted PAR, crop growth rate and relative growth rate. It was found that thiourea brought a positive influence on the crop, and the maximum improvement was recorded by foliar spraying of 750 ppm thiourea, which was statistically at par with the foliar spray of thiourea at the concentration of 500 ppm.

JAE 2023, Vol 15

Received: 22 March 2023

Accepted: 15 June 2023

Published: 30 June 2023

<https://doi.org/10.58628/JAE-2315-122>

Associated Editor: Dr. SM Haldhar

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Keywords: Dry weight, Nutrient uptake, Plant height, Soybean, Thiourea

Introduction

Soybean (*Glycine max*) or Miracle crop, is one of the major sources of vegetable oil globally. In India, it is the second most important source of vegetable oil, with a share of 23% in production (National Food Security Mission 2018). It is consumed in the form of vegetable oil, seed and nuggets. It is mainly cultivated in Madhya Pradesh (also known as "soy state of India"), Rajasthan, Karnataka and Telangana. Soybean is considered the richest (40%) and cheapest source of protein (Kumari et al. 2022). Apart from culinary and nutritional values, it is also popularly used in making paints, varnishes and pharmaceuticals. Despite a good status in the area under cultivation, productivity has been recorded to be very low in India and the reason for low productivity has been related to be its physiology, management constraints and external stresses. Good quality inputs can be provided using suitable varieties. 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 (Srivastava et al. 2017). Thiourea is also known to modulate nutrient uptake and assimilation, which helps crop stress tolerance (Choudhary et al. 2017).

By addressing the above-mentioned problems, using a suitable variety and a supplementary source of nutrition can be a way forward to solving productivity-related constraints. The productivity of a crop is absolutely a function of its growth. The influence of growth attributes during the crop growing season gives hope in the

direction of results. Primary growth characters like plant height, stem girth and dry weight can be calculated to evaluate organics' basic cell growth and translocation. Growth rates like CGR and RGR can be used to assess the growth of crops during any interval and this may help in judging the suitable time for the application of the study and conducting further study on the same. Studies on characters like chlorophyll content and intercepted PAR can be a tool to assess the photosynthetic ability of plants, which will eventually lead to better production. Therefore, a study on the mentioned characters during the growth phase of the crop gives an idea about the influence of applied inputs on the ultimate productivity of the crop.

Materials and Methods

Site description

The site of experimentation was Norman Ernest Borlaug Crop Research Centre, which is situated at GBPUAT, Pantnagar. It is 243.84 m above mean sea level at lies on 29° North and 79.50° east longitude. The average rainfall in this area is 1420 mm annually, with the summer being very hot and humid and winters severely cold. During the period of experimentation, average maximum and minimum temperature ranges from 28.5°C-34.2°C and 12.3°C-26.8°C, respectively.

Soil characters

The soil present at the site falls under the category of Mollisols. Initial study of soil sample before sowing states that, the soil is nearly neutral with pH of 6.8. Nutrient status of soil includes 233 kg/ha N, 22.5 kg/ha P, 140 kg/ha K, 20.5 kg/ha S and 0.96 per cent of organic carbon.

Experimental details

The concerned experiment was conducted using 10 treatments with four replications. The treatments combinations were laid out using factorial RBD design during the Kharif season of the year 2020. Two varieties

^aICAR-Indian Agricultural Research Institute, New Delhi -110 012, India

^bGovind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand- 263 145, India

#Corresponding author DK Meena, E-mail: deepak160798@gmail.com

were used under first factor (A) namely, PS 1347 and SL 958 and five foliar spray treatments including control, water spray and three concentrations of thiourea were taken under the second factor (B). Thiourea spray @ 250, 500 and 750 ppm were applied on foliage at 23 and 54 DAS. The crop was cultivated following all the standard practices, and the foliar spray treatments were administered to the crop accordingly. Proper management of weed, insects and diseases were carried out. PS 1347 is known to have resistance from YMV, bacterial pustules and girdle beetle and is reported to be tolerant to Rhizoctonia blight. On the other hand, SL 958 is also resistant to YMV and Soybean mosaic virus. Thiourea being the analogue of urea, will provide nutrients to the crop and along with that, the application of sulphur is also expected to improve the growth and quality of the soybean crop.

Data collection and observations

To assess the influence of nutrients, the observations were recorded from five tagged plants in each plot and the average of obtained data was analysed. Data like plant height, plant dry weight, stem girth, number of pods, number of branches, and seed index are directly-measured from the representative samples from each plot. Characters like CGR and RGR are calculated using the data obtained from the plants. Representative samples are also utilised 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.

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 utilised for calculation of LAI:

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

Similarly, CGR and RGR were calculated by using following formulae:

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

$$\text{Relative growth rate (g/g/day)} = \frac{(\log_e W_2 - \log_e W_1)}{t_2 - t_1}$$

W_1 = Total dry matter at time t_1

W_2 = Total dry matter at time t_2

t_2 = time of second observation

t_1 = time of first observation

P = ground area covered by plant.

The statistical analysis of data on various recorded parameters of growth, yield, quality and economics was done by using factorial randomized block design as described by Gomez & Gomez (1984) with the help of the standard approach of analysis of Variance (ANOVA). The critical difference (CD) was calculated at a significance

level of 5% to determine whether there were significant differences between the means of the two treatments.

Results and Discussions

Plant height (cm)

One of the most important and evident growth criteria for a plant growth is its height. Plant height was recorded at 30, 45, 60 and 75 DAS and it was found that the two varieties did not show any significant variation in plant height. But, foliar spray of thiourea brought the positive variation in plant height at all the growth stages except 30 DAS. It was recorded that maximum plant height (47.3, 61.2 and 72.7 cm) at 45, 60 and 75 DAS was recorded under the influence of the foliar application of thiourea @ 750 ppm, which was statistically at par with the plant height (46.5, 60.6 and 70.1 cm) recorded by the foliar application of thiourea @ 500 ppm and were superior over the plant height recorded by the application of thiourea @ 250 ppm (41.3, 53.4 and 62.9 cm), water spray (35.9, 44.9 and 55.7 cm) and control (36.0, 44.3 and 55.1 cm). However, the interaction between the varieties and the foliar application of thiourea did not show any significant result.

Similar kind of results were obtained by Amin et al. 2014 and Bangar et al. 2019. The reason behind the positive influence were due to the presence of two macronutrients Nitrogen and Sulphur. Nitrogen improves the activity of growth-promoting hormone, which leads to better cell division and growth. In addition to that, Sulphur aids to the formation of protein which is the building block of living organisms.

Plant dry weight (g/plant)

The use of two different varieties and the foliar spray of thiourea resulted in significant variation in dry matter production of the crop, recorded at 45, 60 and 75 DAS. However, no such variation was recorded in the dry weight of the plant at 30 DAS. Between the two varieties, PS 1347 recorded a higher dry weight than SL 958 at harvest. The increase in plant dry weight of the former variety was of 8.40%. The improvement due to thiourea was also evident as the plant dry weight recorded in the control plot was 5.99, 9.84 and 12.13 g/plant at 45, 60 and 75 DAS which was insignificantly varying with the plant dry weight recorded in the plot in which water spray was carried out. Foliar application of thiourea @ 750 ppm recorded 7.11, 11.77 and 14.83 g/plant dry weight at 45, 60 and 75 DAS. It was equivalent to the plant dry weight recorded under the influence of thiourea @ 500 ppm but was superior over control, water spray and foliar application of thiourea @ 250 ppm. But the interaction of varieties and foliar spray of thiourea could not bring any significant variation. Similar findings were also obtained by Premaradhya et al. 2018 and Meena & Bhati 2016.

Better photosynthetic ability and partitioning of photosynthates in PS 1347 resulted in higher dry weight per plant. An increase in dry weight per plant 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; Sachin et al. 2019).

Stem girth at harvest (mm)

The present investigation showed that two varieties PS 1347 and SL 958 had no significant variation in stem girth. Although, foliar application of thiourea brought improvement in the stem girth of the plant. Maximum stem girth was observed to be 4.78 cm in the case of thiourea application at the rate of 750 ppm. It was statistically at par with the stem girth obtained in the foliar spraying of thiourea at the rate of 500 ppm. Application of thiourea recorded a clear improvement in stem girth over control.

The application of thiourea has improved the girth and it can be concluded that the foliar spraying of thiourea has augmented the plant's sturdiness and can be beneficial in protection against adverse conditions.

Leaf Area Index, CGR and RGR

The results obtained from the data collected showed that both factors brought significant variation in the leaf area index of the crop. PS 1347 recorded a higher leaf area index than SL 958 by 5.1%. Application of thiourea resulted in improvement in leaf area index, the maximum leaf area index was noted to be 3.41 in the case of the thiourea application at the rate of 750 ppm. It was statistically at par with the LAI recorded as a result of 500 ppm thiourea spray, and was superior over the control, water spray and application of thiourea at the rate of 250 ppm. The foliar spray helps maintain turgor pressure in cells and might result in increased LAI.

The crop growth rate was also calculated from the data obtained from the measurement of dry weight pre plant. From the calculated data, it can be elucidated that both the factors i.e., varieties and foliar application of thiourea, brought a significant difference in crop growth rate recorded between 30-45 DAS. Between 30-45 DAS, PS 1347 recorded 13.23 g/m²/day crop growth rate compared to CGR obtained in the case of SL 958 (11.75 g/m²/day). Application of thiourea brought slight improvement in CGR at the dose of 500 and 750 ppm thiourea. But at the later stages, no such improvement

was recorded in the case of CGR between the intervals 45-60 DAS and 60-75 DAS. Regarding relative growth rate, neither the selection of varieties nor foliar spraying of thiourea did not bring any gain or variation in soybean crop.

Photosynthetically active radiation and chlorophyll content

Due to the variation observed in the plant's growth under different treatments, the intercepted PAR by the crop will vary. Intercepted PAR can be expressed in terms $\mu\text{mol m}^{-2}\text{s}^{-1}$, and it was recorded that use of variety could not bring any significant variation in terms of intercepted PAR. Due to the variation in leaf area index, intercepted PAR also varied due to application of thiourea. Like other characters, application of thiourea resulted in maximum and statistically at par intercepted PAR (1116 and 1128 $\mu\text{mol/m}^2/\text{s}$) in the case of application of thiourea at the rate of 500 and 750 ppm, which were superior over control, water spray and thiourea spray @ 250 ppm.

Foliar application of thiourea directly provides nutrients to the growing part of the crop. It ultimately results in better absorption of nutrients and then the formation of chlorophyll in the plant system is positively influenced. This positive influence was also recorded in case of foliar application of thiourea. Readings of SPAD meter reveal that foliar application of thiourea at the rate of 500 and 750 ppm recorded maximum chlorophyll content (41.4 and 42.7). These two were statistically superior over the control, water spray and thiourea application at the rate of 250 ppm. Amanmulla 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).

Table 1. Effect of different treatments on plant height of soybean crop

Treatments	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
Variety				
PS 1347	19.0	42.0	54.3	64.6
SL 958	18.1	40.7	51.4	62.0
SEm±	0.4	0.9	1.4	1.4
CD ($p = 0.05$)	NS	NS	NS	NS
Spray				
Control	18.2	36.0	44.3	55.1
Water spray	18.1	35.9	44.9	55.7
Thiourea @ 250 ppm	18.5	41.3	53.4	62.9
Thiourea @ 500 ppm	18.7	46.5	60.6	70.1
Thiourea @ 750 ppm	19.2	47.3	61.2	72.7
SEm±	0.6	1.5	2.3	2.3
CD ($p = 0.05$)	NS	4.3	6.6	6.6

Table 2. Effect of different treatments on plant dry weight of soybean crop

Treatments	Plant dry weight (g/plant)			
	30 DAS	45 DAS	60 DAS	75 DAS
Variety				
PS 1347	2.40	6.86	11.27	14.04
SL 958	2.24	6.21	10.29	12.86
SEm±	0.06	0.11	0.17	0.23
CD (p = 0.05)	NS	0.33	0.49	0.68
Spray				
Control	2.38	5.99	9.84	12.13
Water spray	2.38	5.98	9.86	12.14
Thiourea @ 250 ppm	2.25	6.52	10.81	13.31
Thiourea @ 500 ppm	2.28	7.07	11.65	14.83
Thiourea @ 750 ppm	2.30	7.11	11.77	14.83
SEm±	0.09	0.18	0.26	0.37
CD (p = 0.05)	NS	0.52	0.77	1.07

Table 3. Effect of different treatments on stem girth and LAI of soybean crop

Treatments	Stem girth at harvest (mm)		LAI
Variety			
PS 1347	4.53		3.11
SL 958	4.42		2.96
SEm±	0.05		0.04
CD (p = 0.05)	NS		0.13
Spray			
Control	4.19		2.55
Water spray	4.25		2.80
Thiourea @ 250 ppm	4.45		3.07
Thiourea @ 500 ppm	4.71		3.34
Thiourea @ 750 ppm	4.78		3.41
SEm±	0.07		0.07
CD (p = 0.05)	0.21		0.20

Table 4. Effect of different treatments on CGR of soybean crop

Treatments	Crop growth rate (g/m ² /day)		
	30-45 DAS	45-60 DAS	60-75 DAS
Variety			
PS 1347	13.23	13.07	8.19
SL 958	11.75	12.11	7.59
SEm±	0.40	0.59	0.80
CD (p = 0.05)	1.17	NS	NS
Spray			
Control	10.71	11.40	6.78
Water spray	10.66	11.49	6.77
Thiourea @ 250 ppm	12.66	12.69	7.41
Thiourea @ 500 ppm	14.19	13.55	9.42
Thiourea @ 750 ppm	14.22	13.80	9.08
SEm±	0.64	0.93	1.26
CD (p = 0.05)	1.86	NS	NS

Table 5. Effect of different treatments on RGR of soybean crop

Treatments	Relative growth rate (mg/g/day)		
	30-45 DAS	45-60 DAS	60-75 DAS
Variety			
PS 1347	70.08	33.19	14.01
SL 958	66.93	33.71	14.12
SEm±	2.61	1.53	1.40
CD (p = 0.05)	NS	NS	NS
Spray			

Control	61.61	32.99	12.39
Water spray	61.67	33.43	12.91
Thiourea @ 250 ppm	68.71	33.65	13.68
Thiourea @ 500 ppm	75.27	33.44	15.84
Thiourea @ 750 ppm	75.27	33.73	15.47
SEm±	4.13	2.42	2.21
CD ($p = 0.05$)	NS	NS	NS

Table 6. Effect of different treatments on intercepted PAR and chlorophyll content

Treatments	PAR ($\mu \text{ mol/m}^2/\text{s}$)	Chlorophyll content (SPAD)
Variety		
PS 1347	1065.0	39.4
SL 958	1022.1	37.9
SEm±	16.8	0.6
CD ($p = 0.05$)	NS	NS
Spray		
Control	966.8	35.3
Water spray	966.0	35.5
Thiourea @ 250 ppm	1041.0	38.4
Thiourea @ 500 ppm	1116.0	41.4
Thiourea @ 750 ppm	1128.0	42.7
SEm±	26.6	0.9
CD ($p = 0.05$)	77.1	2.6

Conclusion

The present investigation highlights the fact that the foliar application of nutrients is beneficial for the overall growth of the crop. Nutrients like nitrogen and sulphur present in thiourea resulted in improvement in plant height, stem girth, considerable in plant dry weight, and improvement in LAI and CGR at the early stage of crop growth. Yield influencing or basically photosynthesis influencing characters like chlorophyll content and intercepted PAR are also positively influenced. However, it could not bring any variation in RGR and CGR at later stage of the crop growth. Two varieties PS 1347 and SL 958 almost performed at par in terms of growth characters except in some cases. Thus, it can be stated that both varieties are compatible with the growing region, and the foliar application of thiourea at the rate of 500 and 750 ppm resulted in the best outcomes. But, to save the inputs used for crop production and obtain a stabilized B: C, foliar application of thiourea at the rate of 500 ppm can be advisable. However, recommendations must be revisited time to time as the one-year experimental trial is, moreover, a way forward to explore the foliar application of thiourea as an additional nutrient management option.

Declaration of Interest

The authors have declared that no competing interest exists.

Data Sharing

All relevant data are within the paper and its supporting information files.

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