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Root growth, yield components, and quality of Redgram (*Cajanus cajan*) as influenced by foliar spray of humic acid

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ABSTRACT

The present study examined the effect of foliar spray of humic acid on root growth, yield components, and quality in Redgram (Cajanus cajan). The study was conducted during Kharif 2019-20 at Main Agricultural Research Station, UAS, Raichur by using a randomized block design. The effectiveness of humic acid was studied with different levels as T1 - Humic acid liquid 15% @ 1.0 ml/l of water, T2 - Humic acid liquid 15% @ 1.5 ml/l of water, T3 - Humic acid liquid 15% @ 2.5 ml/l of water, T4 - Humic acid liquid 15% @ 4.0 ml/l of water, T5 - Planofix 4.5 % @ 20ppm and T6 - as a control. The redgram productivity is limited by flower and pod drop during the crop growth. Management of same through foliar application of humic acid 15% is planned. Result of the research study revealthat redgram root growth including root length, shoot length, root dry weight , shoot dry weight , leaf area, dry matter production, flower drops, minerals content (quality), and yield components was measured at 60,90 DAS and at harvest, respectively. Significant differences (p<0.5) were observed for all the above-mentioned parameters across the humic acid levels. Based on this study, the foliar application T4-Humic acid liquid 15% @ 4.0 ml/l of water may be recommended to improve growth physiology, quality, and yield components of the program in similar environmental conditions. Further, research is required in diverse plant environments to determine economically feasible application levels of Humic acid while comparing it with other plant growth regulators sources.

Keywords: *Humic acid, growth , shoot length , root length , flower drop, mineral content, and yield*

INTRODUCTION

Pulses as one of the most important plant resources are full of protein and after grains are considered as the second most important source of food for human beings. The rate of protein in legumes grains is twice or three times more than that of grain cereals and 10 to 20 times more than that of tuberous crops like potatoes [27]. Pigeonpea (*Cajanus cajan*) is cultivated on an about 4.83 million hectares in the world with an annual production of 2.98 million tonnes and a productivity of 700 kg ha^{-1}. It is an important pulse crop in India, which accounts for an about 90 percent (3.88 m ha) of the total world area and production (2.92 m tons) with a productivity of 860 kg ha^{-1}. In Karnataka, pigeon pea occupies second place in the area (0.80 m ha) and production (0.42 m tons) with a productivity of 860 kg per ha [8] . Gulbarga called as dal bowl, is a very potential district in the Northern Karnataka state for extensive cultivation of pigeon pea. Pigeonpea is intrinsically perennial, but it is generally grown as an annual crop. The initial vegetative growth takes place during the monsoon and floral initiation to the end of the grain filling phase occurs in the winter season; which is generally dry and the pigeon pea crop depends on their continued development on stored moisture. As a result, program consumption in most of the low-income countries like India has increased from 22% - 66%. Despite all these achievements, yields for the rainfed area are generally low and variable due to sparse, erratic rainfall and marginal soils.

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Humic acids (HAs) are the main fractions of humic substances (HS) and the most active components of soil and compost organic matter. They exert indirect and direct effects on plants [13] and this action of HS is dose-dependent and high concentrations of HS are inhibitory for nutrient accumulation [11]. Some plant hormone-like substances seem also to be present in the HS, thus exerting a possible stimulating effect on growth [35]. Humic acid is a commercial product that contains many elements which improve the soil fertility and increase the availability of nutrient elements and consequently affecting plant growth and yield. Humic acid particularly is used to remove or decrease the negative effects of chemical fertilizers and some chemicals from the soil. The major effect of humic acid on plant growth has long been reported. There is basic agreement on the benefits of humus, but there is quite a controversy on the benefit of the application of applied humate (the deposits containing the humic acids). Humic acid is extracted from different sources such as soil, humus, peat, oxidized lignite, and coal. Humic acid can directly have positive effects on plant growth and increases the growth of shoots and roots, and absorption of nitrogen, potassium, calcium, magnesium, and phosphorus by plants. Humic acid is consistent with nature and is not dangerous for the plant and the environment [31] in horse bean. [2] Humic acid increases plant growth through chelating different nutrients to overcome the lack of nutrients, and has useful effects on growth increase, production, and quality improvement of agricultural products due to having hormonal compounds. Among legume family plants, the humic acid foliar spray has remarkable effects on the vegetative growth of the plant and increases photosynthetic activity and leaf area index [18] in corn. The results of the research on wheat showed that the interactive effect of different concentrations of humic acid at three foliar spraying times on leaf area was significant [30], [38] stated that humic acid could sustain photosynthetic tissues and thus total dry weight would increase. To manage agriculture production in unfavorable soil conditions by enriching their organic matter, various options are found in the literature for example, crop rotation, green manures, residue, and humic acid application [14] in wheat ; [37] in potato ; [24] in sweet corn; [29] in compost. To improve the yield and quality of crop plants with foliar application of humic acid was studied[40]. Many studies have demonstrated the foliar application importance of humic acid in agriculture for example [34] in higher plants, [14] in broadbean , [12] in maize, [20] in wheat and [22] have reported beneficial effects of foliar application of humic acid substances on plant growth physiology, mineral nutrition, seed germination, seedling growth, root initiation, root growth, shoot development, yield and the uptake of macro-and microelements. [30]) They have indicated that humic substances might counteract abiotic stress conditions e.g., un-favorable temperature, pH, and salinity enhancing the uptake of nutrients and reducing the uptake of some toxic elements. However, [20] they have reported that humic acid neither improves crop nutrient uptake nor productivity in vegetable crops. [9] investigated the effect of humic substances originating from various organic materials on the growth and nutrient absorption of barley during hydroponic cultivation. They found that doses representing less than 10 mg L−1 carbon favored plant growth, while higher doses sometimes inhibited it. The absorption of macronutrients was significantly affected by the addition of humic substances but differed for each nutrient. [39] applied increasing doses of humic acids, varying from 500 to 2000 mg per kg, at different times before lettuce seedling transplantation, to experimental soil placed in pots. Especially early application of humic acids had positive impacts on the plant growth and nutrient contents of lettuce plants with a short growing period. Also, no comprehensive study is available on the optimization of humic acid for any crop, especially for redgram flower drop management and enhancing the productivity and production. The present study for that reason explores full potential of the foliar application of humic acid on growth physiology, mineral content, and yield component program seed production with optimization of foliar application levels of humic acid .The research findings of this study are based on the key parameters necessary for the evaluation of red gram growth physiology, quality, and yield, and are hoped to be valuable information for farmers and researchers.

MATERIALS AND METHODS

A field experiment was conducted to find out the effect of foliar spray of humic acid on root Growth physiology, yield components, and quality in Redgram during Kharif 2015-16 at Main Agricultural Research Station, UAS, Raichur. The data of prevailing climatic parameters were collected from the research center meteorological station which is located within one kilometer of the experimental area. The crop was sown on 17th July, 2015 by manual line sowing 90 cm row spacing and 30 cm between plants. The program variety selected for the study was TS-3R released by the University of Agricultural Sciences, Raichur. It is a high-yielding variety. The humic acid was sprayed three times at 60-90 days after sowing, at the time of flowering and pod development stage. The concentration of Humic acid for each treatment was sprayed at different levels as T_1- Humic acid liquid 15% @ 1.0 ml/l of water, T_2 -Humic acid liquid 15% @ 1.5 ml/l of water, T_3 -Humic acid liquid 15% @ 2.5 ml/l of water, T_4- Humic acid liquid 15% @ 4.0 ml/l of water, T_5 - Planofix 4.5 % @ 20ppm and T_6 - control. The observations on various root growth physiological parameters viz., root length were measured by meter scale . While the fresh weight and dry weight of roots, the root sample was placed in the oven for 48 hours at 75°C and then it was weight by a digital scale with an accuracy of 0.01 g balance. Root volume was measured by the water displacement method. The dried plant seeds material was ground and digested with a diacid 2:1mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$) to determine the various macro and micro nutrient content from program seeds with Atomic absorption spectroscopy for Fe, Cu, Zn and flame photometry for K.

Leaf area : The leaves from three selected plants from each treatment were used for the estimation of leaf area. Leaf area was computed by using disc method and expressed as cm2 plant-1 at 60, 90 DAS and at harvest. The procedure of Stickler et. al., (1961) was adopted.

Total dry matter production per plant (g)

Three plants from each treatment were selected randomly, separated into leaf and stem, and then they were chopped into small pieces to enable drying and were oven dried at 80 oC to a constant weight. The oven dry weight of stem along with leaf was used to work out dry matter production (g) per plant

Root characteristics

Root length (cm)

The length of randomly selected tagged plants at harvest was recorded in centimeter, then mean root length was worked out.

Root fresh and dry weight (g)

The fresh and dry weights (dried at 80^{0}C) of roots of the randomly selected tagged plants at harvest were recorded in gram, then mean weight was worked out.

Root volume (cc)

The root volume was determined by water displacement method. The randomly selected five roots were immersed individually in a container containing water and the amount of water displaced by each root was measured and the average volume of root was expressed in cubic centimeter (cc).

Estimation of mineral content

Copper (Cu), Zinc (Zn), Iron (Fe) and Manganese (Mn) contents in seed samples were estimated using Atomic Absorption Spectrophotometer (AAS-4141, Electronic Corporation of India Ltd.).

Digestion of seed samples

Seed samples were dried at 65 ± 1º C, ground thoroughly in Wiley mill and were taken for analysis of minerals content. A representative sample (0.5 g) was taken into a 100 ml conical flask for pre-digestion and soaked over night with 10 ml of concentrated HNO3 and next day finally digested in a tri-acid mixture HNO3 : H2SO4 : HClO4 in the ratio of 10 : 1: 4.The content were gently heated on a hot plate using sand bath, until the volume was reduced upto 4.0 ml or even less till brown fumes cease leaving and only snow white residue was left in the conical flask. The residue was cooled, to which 20 ml of 6N HCl was added to each sample, then filtered through Whatman No.42 filter paper and diluted with distilled water to make up the volume to 100 ml. and used for analysing Cu, Zn, Fe, and Mn. The concentration of micronutrients from the standard curve of known concentration and in seed samples were expressed in mg / kg or ppm.

The minerals content was calculated using the following formula.

Minerals content (ppm) =Average ppm volume of digested sample vol. made up 106 weight of the sample Aliquot taken

RESULT AND DISCUSSIONS

Leaf area (cm^2 per plant) and total dry matter production (g/plant)

The data pertaining to leaf area total dry weight trend (Fig. 1 & 2) shows that at different growth stages, total dry weight of the plant has increased gradually and all the treatments differ significantly to each other. As it is observed, the total dry weight of the redgram plant in treatment with 4.0 ml /l of water humic acid is more than that of other treatments. This shows that as humic acid concentration increases, total dry weight also increased. The results of this study are in conformity with the findings of [31] in Horsegram , [39] in tomato stated that humic acid could improve the activity of photosynthetic tissues in crop plants and thus leaf area & total dry weight would increase at all the stages . All levels of humic acid 98 days after sowing maximized leaf area & dry matter accumulation and then they showed a descending trend. The plants own its accumulated dry matter into reproductive organs, and the loss of leaves led to a decrease in dry matter accumulation. The highest descending trend was observed in control treatments due to the lack of absorption of humic acid by the leaves [32] showed that the application of humic acid foliar sprays had a key role in increasing the yield. The results were consistent with the findings of [13] in potatoes and [45] in maize, and [4] in soybean

Root growth parameters

The data on root development at harvest presented in Table 1 indicated significant differences between the treatments. The all the treatments differed significantly in root length(cm) , root fresh weight(mg) , and root dry weight (mg), and T_4 recorded significantly higher root length(cm) , root fresh weight(mg) , root dry weight (mg) (24.25, 27.12, 9.93, respectively) as compared to all other treatments. While significantly lower root length (cm), root fresh weight (mg), and root dry weight (mg) were recorded in control (10.92, 19.7, 4.60, respectively), but it was on par with T_1. These findings are in good agreement with the growth-promoting results of humic substances those reported for a wide number of plant species ([42] in soil; [11]. The good results of the potato field trial correspond with the conclusions of a study in 2005 from the Potato Research Institute in Finland [28] In this study, Humifirst also had a positive effect on total tuber yield (+ 17% compared to control) and marketable yield (+ 24% compared to control). The best response was obtained when Humifirst was applied to the soil just before seedbed tillage, which is similar to our experiment, compared to later application on planting and hilling. Other positive effects of Humifirst on potato yield were found at Gembloux (+ 25%) and Geer (+ 11%) both located in the southern part of Belgium [7], [16] detected that humic substances accelerated both the vegetative and reproductive growth of maize plants and thus stimulated optimal production of plant biomass (shoot and cobs). Root growth was stimulated as well with more fine lateral and secondary roots in the humic substances treatments. In line with these results While , [38] also reported that sprayed 50 to 300 mg per kg humic acids on the soil in a pot experiment with maize and found that the addition of 50 and 100 mg kg^{-1} caused a significant increase of 20 and 23% in shoot and 39 and 32% in root dry weight. The incorporation of humic substances in the soil stimulated the root mass of creeping bentgrass with 45% in the 0 to 10 cm depth and with 38% in the 10 to 20 cm depth [13] .Above-ground biomass was only slightly promoted and was attributed by the authors to a sufficient nutrient supply.

The data on flower drops (%) at flowering development presented in Table 1 indicated significant differences between the treatments. The all the treatments differed significantly in flower drops and T_4 recorded significantly lower flower drops (45.8 %) as compared to all other treatments. While significantly higher flower drops were recorded in control (65.4%). These results are in good agreement with the findings of [31] in horse been; [31] in groundnut, and [39] in tomato. Similarly, [5] stated that that humic acid increases plant growth through chelating different nutrients to overcome the lack of nutrients, and has useful effects on growth increase, production, and quality improvement of agricultural products due to having hormonal compounds. [18],they stated that in legume family plants, humic acid foliar spray has remarkable effects on the vegetative growth of plants (plant height, number of branches) and increases photosynthetic activity and leaf area index. [31] in horse been investigated the effect of humic acid on the growth parameters of cowpea and found that humic acid would increase leaf area , total dry matter, and leaf area index. [1] and [15], on onion plants, and [19] on squash reported that humic acid applications led to a significant increase in soil organic matter which improves plant growth and crop production. [40] with study the effects of mineral fertilizers and humic substances on the growth and yield of cowpea was reported that, the combination of chemical fertilizers with an application of humic substances improves the growth and yield of cowpea.

Seed quality parameters

The data on seed quality i.e. macro-nutrient (%) and micro-nutrients content (ppm) of red gram seeds at harvest presented in Table 2 indicated significant differences between the treatments. The all the treatments differed significantly in Macro-nutrient (%) and micro-nutrients content (ppm) and T_4 recorded significantly higher Macro-nutrient (4.92 ,0.952, 3.80 %, N P K, respectively) and micro-nutrient content (2.98, 10.60, 5.59 ppm Cu, Zn, Fe, respectively) as compared to all other treatments. While significantly lower macro-nutrient (%) and micro-nutrients content (ppm) was recorded in control (1.87, 0.259, 1.13 %, NPK, respectively) and micro-nutrients content (1.50, 6.65, 3.50 ppm Cu, Zn, Fe, respectively) , but it was on par with T_1. Our results are supported by [14], and [33] who have reported that humic substances provoked a better efficiency of plant water uptake and improved the mineral nutrition and grain protein content. Similarly, our results are further supported by [41] that salinity had negative impacts on the dry weight and the N, P, K, Ca, Mg, Fe, Cu, Zn, and Mn uptake of maize plants, the humic acid mitigates salinity and increase dry weight and nutrients composition of plants. Similar to this the foliar application of humic acid affected the uptake of P which was statistically significant in the uptake of Na, K, Cu, and Zn. However, its amounts were not found statistically significant with other nutrients. The highest dry weight and nutrient uptake were obtained with a 0.1% dose of humic acid. Nevertheless, the dry weight and nutrient uptake were decreased at 0.2% dose of humic acid, but the amounts except for Fe, Cu, and Mn were found higher than in the control [23]. Similarly, [17] studied the effect of foliar application of humic acid extracts on young olive plants in greenhouse and infield experiments. Under field conditions, shoot growth and accumulation of potassium (K), boron (B), magnesium (Mg), calcium (Ca), and iron (Fe) in leaves were promoted. The effects of humic substances on plant production and nutrient absorbance generally depend on their origin, type, and concentration and on the species and variety of the plant treated [42]; [11].

Yield and yield components

The data on pods and yield of the program was significantly influenced by humic acid Liquid 15% application (Table 3). Significantly higher red gram pod yield was recorded with the application of 4.0ml/L of 15% of humic (2,154 kg/ha) followed by the application of Humic acid liquid 15% @ 2.5 ml/l of water (1323.02 kg/ha). However, lower pod yield was recorded in the untreated control (1073.88 kg/ha) the extent of reduction in pod yield was 32 % University check Planofix 4.5 % @ 20ppm (1288.66 kg/ha). Similarly, a higher number of pods and pods weights were also recorded in T_4 (126.88 and 75.45, respectively) while a lower number of pods and pods weights were recorded in control (89.38 and 44.88, respectively). Similar results were obtained by [25]in groundnut; [26] in wheat , [19]in squash plants; [9]in barley, [21] in groundnut, [13] in peanutand [10] in peanuts. [43] in rice ; [20] in vegetables ; [3] in peanut.

CONCLUSIONS

Application of humic acid substances at the start of the growing season induced an overall positive effect on growth, root development, seed quality, and yield of red gram in the field. It was also observed that the foliar application of all the doses of Humic acid Liquid 15% on program significantly increased the root length per plant , root dry weight per plant root volume, number of pods/plant and yield /ha. Further, there was a significant reduction in the flower and pod drop compared to the control. The seeds/plant analysis for quality aspects indicated significantly higher content of macro (N, P.K) and micronutrients (Cu, Mn, Zn, and Fe) with the foliar application of Humic acid Liquid 15% @ 4.0ml/L over the control. The application of Humic acid liquid 15% @ 4.0ml/L at the flower bud formation stage may reduce flower drops in program compared to the control. Increment in Humic acid concentration increased root growth and quality of red gram in the present study. Based on the present study findings Humic acid Liquid 15% @ 4.0ml/l foliar application to may be recommended. Further research is required in diverse plant environments to determine economically feasible application levels of Humic acid while comparing it with other manures and organic fertilizer sources.

Future scope of study: The strategies for future research and development to improve the efficiency and acceptability of foliar application of humic acid in agriculture are outlined below; a study is needed for comparison of bio-efficacy of humic aicd with respect to yield and yield components in other varieties of redgram.The study relating to various enzymatic changes in the crop plant by the folai application of humic aicd may be undertaken. Intensive research is needed to determine the duration up to which the humic acid remains active in the plant system and its metabolism. Response of crops to humic acid under different a biotic stress conditions may be evaluated for their efficient utilization in agricultural and horticultural crops. Systematic study on source-sink relationship may be done along with the foliar application of humic acid in all pulse crops.

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Table 1. Effect of foliar application of humic acid on root characteristics and Flower drops (%) at flowering development in redgram

Treatments	Root length (cm)	Root fresh weight(g)	Root dry weight (mg)	Root volume (cc)	Flower drops (%)
T_1 = Humic acid liquid 15% @ 1.0 ml/l of water	15.24	21.67	5.83	45.82	58.2
T_2 = Humic acid liquid 15% @ 1.5 ml/l of water	18.81	23.58	7.48	48.55	57.4
T_3 = Humic acid liquid 15% @ 2.5 ml/l of water	21.98	25.64	8.63	49.50	53.2
T_4 = Humic acid liquid 15% @ 4.0 ml/l of water	24.25	27.12	9.93	52.08	45.8
T_5 = Planofix 4.5 % @ 20ppm	18.52	24.87	8.78	45.39	55.3
T_6 = Control	10.92	19.07	4.60	43.80	65.4
S.Em (±)	**1.86**	**1.60**	**1.59**	**1.78**	**2.57**
C. D. (5%)	**5.60**	**4.84**	**4.78**	**5.38**	**7.74**

DAS = Days after sowing

Table 2. Effect of foliar application of humic acid on macro and micronutrient at harvest in redgram

Treatments	Macronutrient			Micronutrient		
	N (%)	P (%)	K (%)	Cu (ppm)	Zn (ppm)	Fe (ppm)
T1 = Humic acid liquid 15% @ 1.0 ml/l of water	2.69	0.437	1.28	1.93	7.48	3.88
T2 = Humic acid liquid 15% @ 1.5 ml/l of water	2.92	0.575	1.37	2.31	7.93	4.55
T3 = Humic acid liquid 15% @ 2.5 ml/l of water	3.62	0.765	2.73	2.42	8.78	5.03
T4 = Humic acid liquid 15% @ 4.0 ml/l of water	4.92	0.952	3.80	2.98	10.60	5.59
T5 = Planofix 4.5 % @ 20ppm	3.75	0.521	1.58	2.35	8.40	4.73
T6 = Control	1.87	0.259	1.13	1.50	6.65	3.50
S.Em (±)	**0.454**	**0.147**	**0.34**	**0.19**	**0.67**	**0.39**
C. D. (5%)	**1.382**	**0.444**	**1.04**	**0.57**	**2.02**	**1.18**

DAS = Days after sowing

Table 3. Effect of foliar application of humic acid on yield and yield components at harvest in Redgram

Treatments	Yield components			
	Number of pods per plant	Pod weight (g)	Test weight (g)	Yield (kg/ha)
T1 = Humic acid liquid 15% @ 1.0 ml/l of water	95.35	46.65	7.85	1176.98
T2 = Humic acid liquid 15% @ 1.5 ml/l of water	102.18	51.60	8.58	1254.30
T3 = Humic acid liquid 15% @ 2.5 ml/l of water	116.28	62.38	9.40	1323.02
T4 = Humic acid liquid 15% @ 4.0 ml/l of water	126.88	75.45	9.78	1426.12
T5 = Planofix 4.5 % @ 20ppm	105.10	61.85	8.40	1288.66
T6 = Control	89.38	44.88	7.43	1073.88
S.Em (±)	**6.15**	**6.14**	**0.52**	**39.91**
C. D. (5%)	**18.53**	**18.49**	**1.56**	**120.21**

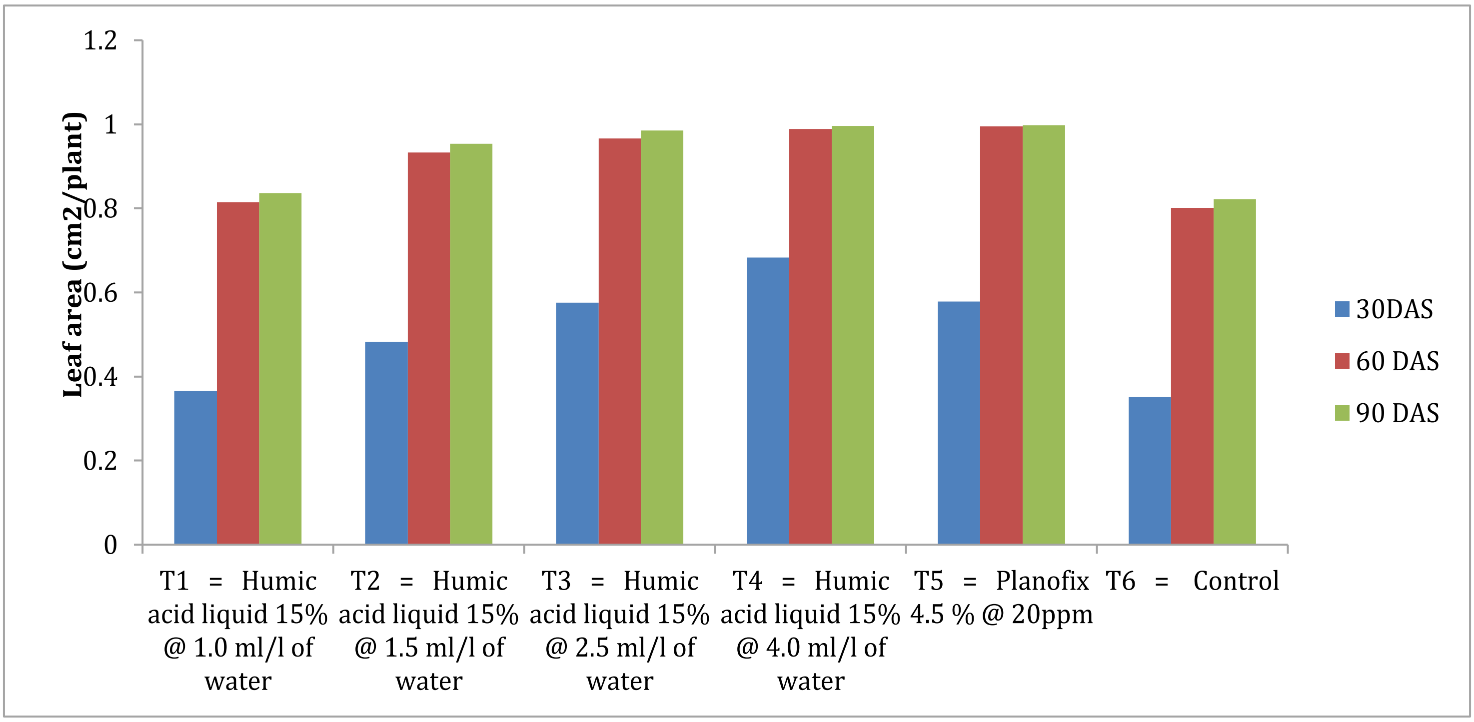

Fig. 1 Influence of foliar application of Humic acid on leaf area (dm2/plant) at different stages of crop growth in Redgram

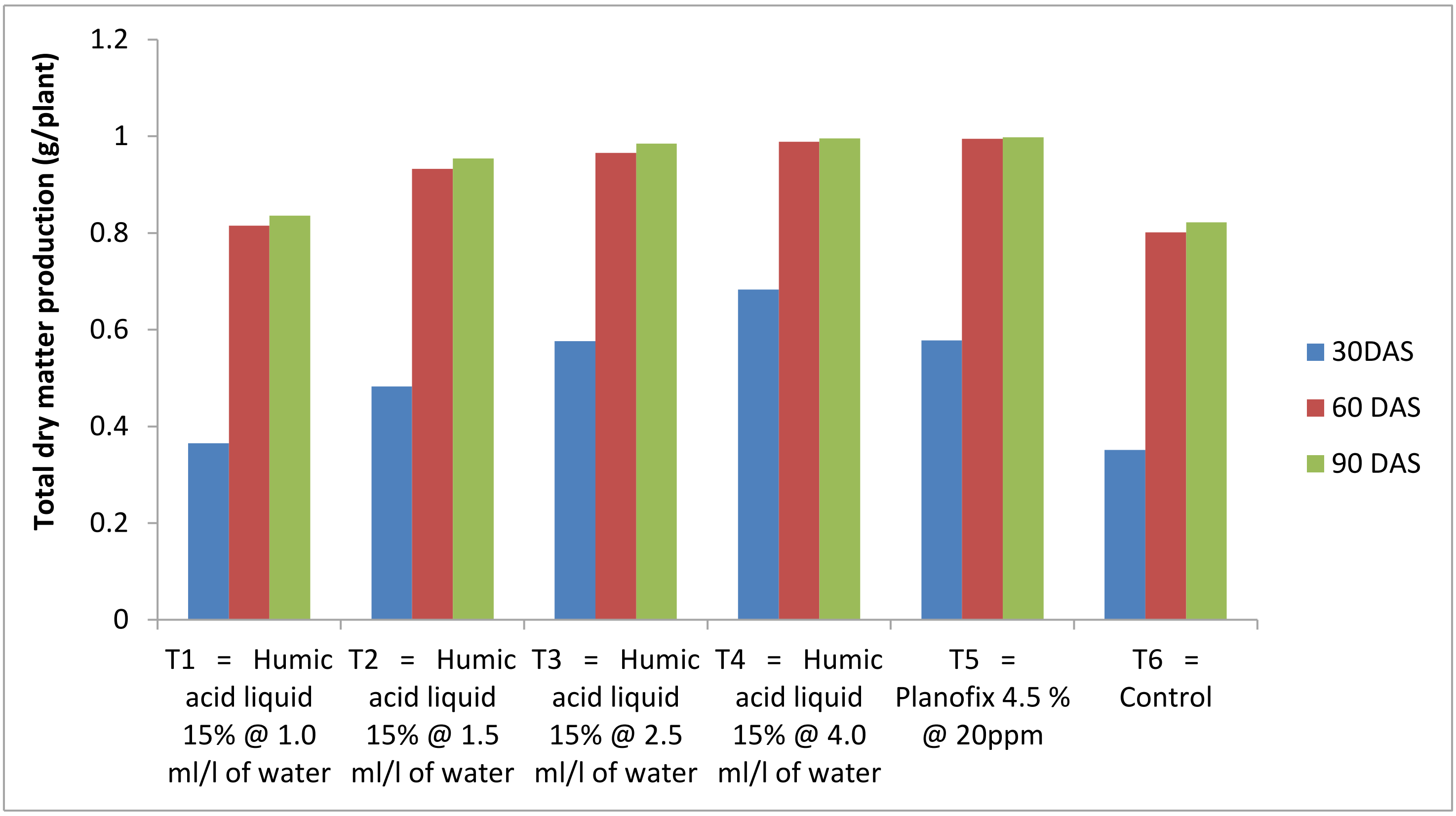

Fig. 2 Influence of foliar application of Humic acid on Total dry matter production (g/plant) at different stages of crop growth in Redgram

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