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Physiological Manipulation of Photosynthetic Efficiency of Blackgram (*Vigna mungo* L.) through Plant Growth Regulators and Nutrients

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A study was carried on the photosynthetic efficiency of blackgram to improve the transport efficiency by foliar application of plant growth regulators and nutrient mixture during *rabi*, 2017-18 as pot culture experiment at glass house of the Department of Crop Physiology. Foliar application of salicylic acid (SA) (250 ppm), mepiquat chloride (MC) (250 ppm), chlorocholine chloride (CCC) (150 ppm) were applied at flower initiation stage and 15 days after the first spray, on blackgram with and without the seed treatment of salicylic acid (50 ppm). TNAU Pulse Wonder (1%) was applied as foliar spray at peak flowering stage. Among the treatments, Mepiquat Chloride (MC) significantly increased chlorophyll content while TNAU Pulse Wonder recorded higher chlorophyll index, transpiration rate, stomatal conductance, seed yield plant^{-1}and seed index. It is concluded that TNAU Pulse Wonder improved the source-sink relationship compared to other treatments with enhanced physiological, biochemical parameters and yield of blackgram.

Key words: Blackgram, Plant growth regulators, TNAU Pulse Wonder, Photosynthetic efficiency.

Agriculture still remains the backbone of Indian economy in spite of various technological advancements and industrial development with 70 % of people dependent on agriculture and 25 % of country's Gross Domestic Product (GDP) coming from agricultural sector. In Indian agriculture, pulses play an important role and India is a major pulse growing country. The pulses fit well in crop rotation and crop mixture thus forming an integral part of cropping system of Indian farmers. Pulses are the cheapest source of quality protein and they provide the protein component for a balanced diet of the people (Sritharan *et al.*, 2015). The per capita consumption of pulses in our country is just 40 g which is lower than the recommendation of the Indian Council of Medical Research (ICMR) and World Health Organization (WHO) which is 45g and 80g respectively. Thus, the requirement of pulses as per the recommendations of ICMR and WHO for billion people would be 17.15 million tonnes and 29.2 million tonnes respectively (Jagannathan *et al.*, 2000).

Blackgram [*Vigna mungo* (L.) Hepper] occupies an important place among the premier pulse crops in India. Blackgram is an extensively grown grain legume and belongs to Fabaceae family and got noticeable significance from the point of food and nutritional security in the world (Thakur *et al.*, 2017). Blackgram is a perfect combination of all nutrients which include 20 to 25% proteins, 40 to 47% starch, ash fats, carbohydrates and essential vitamins (Manjri *et al.*, 2018). Regarding the states, Uttar Pradesh and Maharashtra occupy the first two positions, contributing over 32%. Individually, Madhya Pradesh and Andhra Pradesh contribute 14% each to the total production (GoI, 2014-15). In Tamil Nadu, blackgram is cultivated in 0.365 m ha with a production of 0.31 million tonnes with an average productivity of 851 kg ha^{-1} (TNstat, 2014).

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Plant growth regulators are chemicals which provide optimum vegetative growth and increased source partitioning in the reproductive organs so that the yield is sufficiently increased by regulating plant growth and architecture. Ever since their invention, plant growth regulators have emerged as "magic chemicals" that could increase agricultural yield at an appealing rate. Plant growth regulators when added to the plant in a very minute concentration at critical growth periods stimulate the regulatory mechanism from seed germination to senescence in a variety of crop plants. The increased source-sink relationship using growth regulators includes enhanced transport of assimilates from source and thereby increases productivity (Shinde, 2010).

Material and Methods

The pot culture experiment was conducted in the Glass house of the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during *rabi*, 2017-18 with blackgram variety CO 6. The location is in Western Agro-Climatic Zone of Tamil Nadu at 11.01°N latitude and 76.39°E longitude and at an altitude of 426.7 m above MSL.Red sandy soil was used for pot culture experiment at glass house. Soil mixture was prepared by using red soil, sand and farmyard manure (FYM) in the ratio of 2:1:1.

Medium size pots were filled with 12 kg of soil. The experimental design was completely randomized design with 10 treatments and 3 replications. Crop received recommended dose of fertilizers (25 kg N + 50 kg P_2O_5 + 25 kg K_2O ha^{-1}). The treatment included foliar spray of salicylic acid (250 ppm), mepiquat chloride (250 ppm), Chlorocholine chloride (150 ppm) and TNAU Pulse Wonder (1%) and control. The treatments were similarly given to seed treated (salicylic acid, 50 ppm) and non-treated blackgram plants. SA, MC, CCC were applied at flower initiation and 15 days after first spray whereas TNAU Pulse Wonder was applied at peak flowering stage.

Gas exchange parameters *viz*., photosynthetic rate, transpiration rate and stomatal conductance were recorded using an advanced portable photosynthesis system (PPS) (Model LI-6400 XT, Licor Inc, Nebraska, USA). The total chlorophyll content was estimated by adopting the procedure of Arnon (1949) and the content was expressed as mg g^{-1} of fresh weight. SPAD readings were recorded by using chlorophyll meter (SPAD 502) designed by the soil plant analytical development (SPAD) section, Minolta, Japan. The hundred seed weight was recorded in gram on the basis of randomly selected 100 seeds from each of the three plants. The plants harvested from each treatment were threshed and the seed yield was recorded and expressed in grams $plant^{-1}$ from the dried whole plant sample.

Results and Discussion

Chlorophyll content

Chlorophyll content significantly increased due to the application plant growth regulators and nutrients. Among these, mepiquat chloride (250 ppm) (3.42 mg g^{-1}) with seed treatment (C_1T_3) recorded maximum total chlorophyll content at 55 days after sowing (DAS) which was followed by TNAU Pulse Wonder (1%) (3.41 mg g^{-1}) with seed treatment (C_1T_5), mepiquat chloride (250 ppm) (3.14 mg g^{-1}) without seed treatment (C_2T_3) and Chlorocholine chloride (150 ppm) (3.12 mg g^{-1}) with seed treatment (C_1T_4).

Table 1. Effect of plant growth regulators and nutrients on total chlorophyll content (mg g^{-1})

Treatments	Pre-flowering (30 DAS)			Post-flowering (55 DAS)		
	C1	C2	Mean	C1	C2	Mean
T_1 – Control	1.45	1.60	1.53	1.81	1.82	1.82
T_2 – Salicylic acid (250 ppm)	1.09	1.59	1.34	2.08	2.04	2.06
T_3 – Mepiquat chloride (250ppm)	2.50	1.69	2.09	3.42	3.14	3.28
T_4 – Chlorocholine chloride (150 ppm)	1.10	1.39	1.24	3.12	2.34	2.73
T_5 – TNAU Pulse Wonder (1%)	1.30	1.14	1.22	3.41	2.87	3.14
Mean	1.49	1.48		2.77	2.44	
SEd		0.02			0.06	
CD (P=0.05)		0.04			0.12	

C_1: Seed treatment with 50 ppm Salicylic acid C_2: Without seed treatment

The maintenance of higher chlorophyll content was due to effect of the treatment in lowering the activity of chlorophyllase enzyme, as the result, the water soluble porphyrin fragments were not exported from chloroplast, thus there was minimum destruction in leaf greenness (Martinoia *et al*., 1982). The TNAU Pulse Wonder, nutrients, MC and CCC played a productive role in upregulating the enzymes involved in the chlorophyll synthesis. Singh *et al.* (2014) reported similar results with mepiquat chloride which increased chlorophyll 'a' and the total chlorophyll content in kabuli gram. The increased chlorophyll content in seed treated plants could be accredited to increased seed vigour (Table 1), as recorded in the present study. The invigorative effect of seed treatment helped the plants to absorb more nutrients from the soil which might be utilized for more chlorophyll production resulting in enhanced photosynthetic activity of seed treated plants. This was in agreement with Sathiya Narayanan *et al*. (2015) who reported similar results with prosopis hardening in blackgram. The variation in chlorophyll content due to growth regulators, organics and nutrients may be attributed to the decreased chlorophyll degradation and increased chlorophyll synthesis which were in

Table 2. Influence of plant growth regulators and nutrients on chlorophyll index (SPAD)

Treatments	Pre-flowering (30 DAS)			Post-flowering (55 DAS)		
	C1	C2	Mean	C1	C2	Mean
T_1 – Control	31.00	24.67	27.83	43.2	42.9	43.05
T_2 – Salicylic acid (250 ppm)	32.07	29.23	30.65	45.8	44.8	45.30
T_3 – Mepiquat chloride (250ppm)	31.40	29.43	30.42	46.6	44.7	45.65
T_4 – Chlorocholine chloride (150 ppm)	34.80	26.10	30.45	48.6	46.3	47.45
T_5 – TNAU Pulse Wonder (1%)	31.73	29.43	30.58	46.8	46.1	46.45
Mean	32.20	27.77		46.2	44.96	
SEd	0.80			1.01		
CD (P=0.05)	1.67			2.11		

C_1: Seed treatment with 50 ppm Salicylic acid C_2: Without seed treatment

accordance with Jeyakumar and Thangaraj (1998) who reported that mepiquat chloride (125 ppm) resulted in higher amount of chlorophyll in groundnut.

Chlorophyll index

The data indicated that plant growth regulators and nutrients had marked influence on Chlorophyll index and showed an increasing trend from vegetative to post-treatment stage. Chlorocholine chloride (48.6) with seed treatment recorded maximum value which was followed by TNAU Pulse Wonder (46.8) with seed treatment. This findings were in confirmity with the reports of Chung *et al.* (1999) who reported that the ancymidol in cycocel stimulated chlorophyll biosynthesis in *Bletilla striata.* The high chlorophyll content upon plant growth regulators application might be attributed to the protection of chlorophyll molecule from photo oxidation, increased chlorophyll synthesis and delayed chlorophyll degradation as reported by Dong *et al*. (2008) in soybean. The nutrients and plant growth regulators within the TNAU Pulse Wonder might have increased chlorophyll biosynthesis (Table 2), which reflected on the chlorophyll index observation.

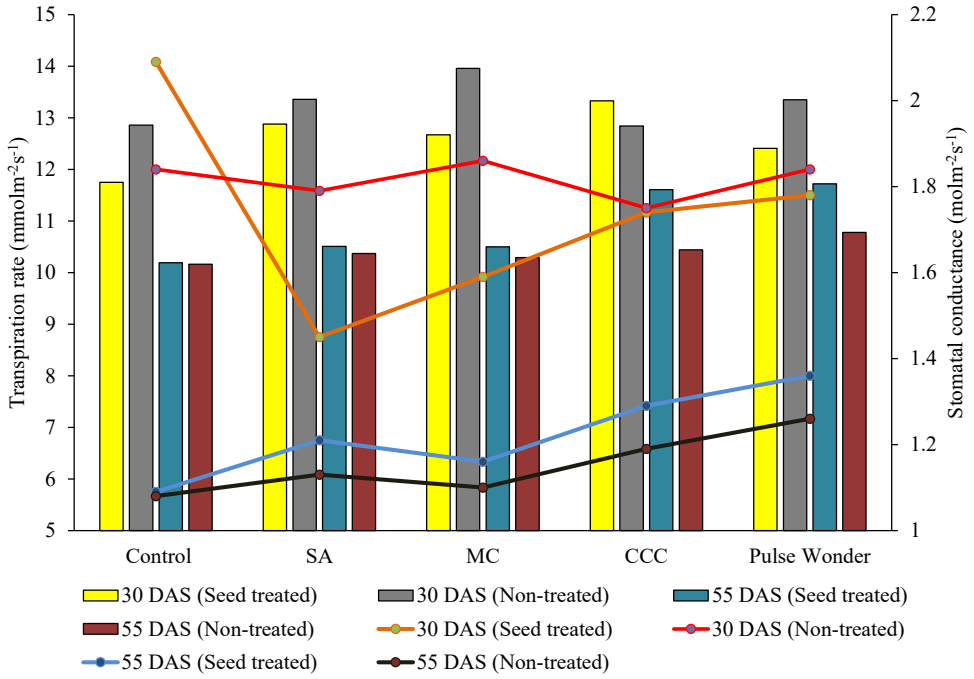

Figure 1. Influence of plant growth regulators and nutrients on transpiration rate ($mmolm^{-2}s^{-1}$) and stomatal conductance ($molm^{-2}s^{-1}$)

Transpiration rate

In the present study, transpiration rate decreased from pre-flowering to the post-treatment stage and within the treatments, it showed significant difference. TNAU Pulse wonder along with seed treatment (C_1T_5) recorded maximum transpiration rate (11.72 mmol $m^{-2}s^{-1}$) which was followed by Chlorocholine chloride with seed treatment (C_1T_4) (11.61 mmol $m^{-2}s^{-1}$). The increased transpiration rate could be attributed to the increased leaf area over control due to the foliar spray of plant growth regulators and nutrients. This increased transpiration rate could be attributed to the increased leaf area. This findings were in agreement with the report of Kumar *et al.* (2001) in water stressed cotton. Data from vegetative phase revealed that seed treatment had no profound effect on the transpiration rate (Figure 1). The increased transpiration rate over control upon treatment with plant growth regulators in the present study was in close confirmity with Fariduddin *et al*. (2003) who reported that salicylic acid at lower concentration (10^{-5} M) when sprayed to the foliage of brassica significantly increased the leaf carbonic anhydrase activity.

Stomatal conductance

Seed treatment had no significant effect on stomatal conductance during the vegetative phase whereas plant growth regulators exhibited marked difference within the treatments. Among the ameliorants, TNAU Pulse Wonder (1.36 mol m-2 s-1) along with seed treatment recorded the highest stomatal conductance which was followed by Chlorocholine chloride (1.29 mol m-2 s-1) with seed treatment. The increased leaf area might be attributed as the reason for increased stomatal conductance of blackgram in the present study (Figure 1). Dodd (2003) reported similar findings that, more efficient gas exchange after using exogenous growth regulators probably occurs through their influence on the development and the number of stomata may be determined by the concentration of a given hormone. The observations of this study were also in close confirmity with the observations of Gupta et al. (1999) that, gas exchange depends

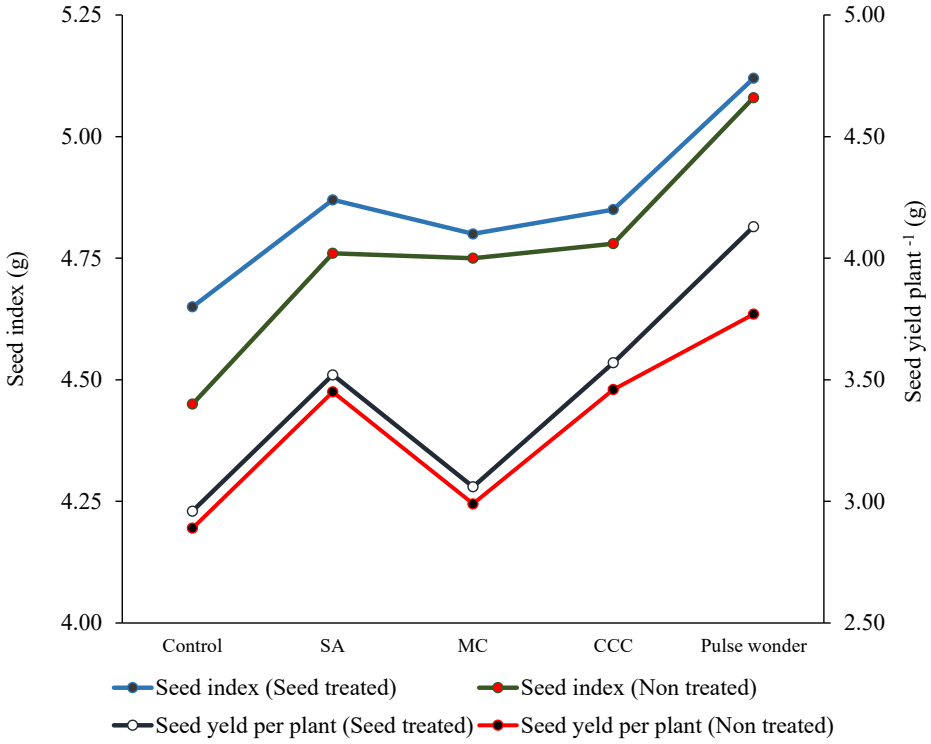

Figure 2. Effect of plant growth regulators and nutrients on seed yield

on the condition like stomatal opening and closure. These observations were in close agreement with the Nowak and Wrobel (2015) that spraying exogenous growth regulators had a significant influence on the number of stomata per unit of surface as well as on the length of their stomatal apertures in soybean.

Seed yield

Seed yield plant^{-1} markedly increased by the application of foliar nutrients. In the current study, TNAU Pulse Wonder with seed treatment increased the seed yield by 39.53% over control followed by TNAU Pulse Wonder without seed treatment by 30.45% whereas CCC with seed treatment increased by 20.61% over control and salicylic acid increased 18.92%. The increased in yield might be due to enhanced yield attributes like number of pods plant^{-1}, number of seeds pod^{-1}. The increased uptake of nutrients by blackgram due to effective translocation of nutrients from sink to reproductive organs of crop may be attributed for the enhanced yield attributes. The present findings was in confirmity with the results of Shinde (2010) due to the application of CCC, TIBA and progib and CCC @ 500 ppm resulted in increased number of pods and seeds thereby increasing the total seed yield. Similar results were obtained by Prabhakar Reddy (2002) due to, the foliar application of salicylic acid in greengram which increased seed yield significantly which supports the results of the present study (Figure 2). The increase in yield upon treatment of plant growth regulators might be due to the beneficial effect of nutrients in combination with growth regulators applied at proper time and stage, which resulted in higher yield as reported by Kumaran and Subramanian (2001) in blackgram. The findings of present study was in agreement with the observations of Marimuthu and Surendran (2015) that, the yield increase with respect to the application of TNAU pulse wonder might be due to the action of this crop booster with a combination of nutrients and growth regulators for pulses resulted in decreased flower shedding and improved crop tolerance for abiotic and biotic stress. The increased seed yield by TNAU Pulse Wonder might be attributed to the composition of this nutrient mixture and was in confirmity with Jayabel *et al*. (1999) who reported that foliage applied macro and micronutrients at critical stages of the crop might be effectively absorbed and transported to the developing pods, producing more number of pods with better filling in soybean.

Seed index

This study revealed that TNAU Pulse Wonder with seed treatment of salicylic acid 50 ppm increased 100 seed weight by 10.11% over control. TNAU Pulse Wonder treatment without seed treatment increased the seed index by 14.15% over absolute control (C_2T_1) followed by seed treated salicylic acid (4.73%) and CCC (4.30%). The increased 100 seed weight might be attributed to increased mobilization of metabolites to the reproductive sinks. Shah and Prathapasenan (1991) studies concluded that the application of CCC as foliar spray significantly enhanced the number of pods, number of seeds and total grain yield in greengram which confirmed the result of the present study (Figure 2). The findings of the present study were in close agreement with the

observations of Marimuthu and Surendran (2015) in blackgram that the production of higher seed yield due to growth regulators might be attributed to the fact that plants treated with growth regulators remained physiologically more active to build up sufficient food reserves for developing flowers and seeds. The increased seed index upon foliar spray of TNAU Pulse Wonder treatment might be attributed to the application of nutrients at reproductive stage which helped in translocation of photosynthates to the developing pods thus helping in better seed filling, increased number of seed pod^{-1} and test weight which was in agreement with the findings of Koester *et al*. (2014) in soybean.

Conclusion

The different plant growth regulators and nutrients used, TNAU Pulse Wonder improved the overall transport efficiency and assimilate partitioning in black gram. It was followed by growth retardant Chlorocholine chloride. Growth promoter salicylic acid and growth retardant mepiquat chloride also had impact on source-sink relationship but the effect was less effective compared to the TNAU Pulse Wonder. TNAU Pulse Wonder improved the source-sink relationship than the other treatments and enhanced the physiological, biochemical parameters and yield of blackgram.

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