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Short communication

Photosynthetic rate, Stomatal conductance and yield of soybean under optimized fertilizer management and varietal selection

K. K. DAKHORE[1*], P. P. SOLUNKE[2], R. NIGAM[3], A. S. JADHAV[4], Y. E. KADAM[1], P. K. PATIL[1] and A. M. KHOBRAGADE[2]

[1]All India Coordinated Research Project on Agrometeorology (AICRPAM), Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani- 431402, Maharashtra
[2]Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani- 431402, Maharashtra
[3]PACD/AESG/EPSA, Space Applications Centre, ISRO, Ahmedabad 380 015
[4]Cotton Research Centre, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani- 431402, Maharashtra
[*]Corresponding Author email: dakhorekk@yahoo.com

Soybean (*Glycine max* L. Merrill) is a globally important grain legume that occupies a unique position between pulses and oilseeds due to its dual role as a protein- and oil-rich crop. Achieving high and stable productivity in soybean depends largely on effective crop management practices that regulate growth, physiology and yield formation. Crop growth is governed by the total photosynthate produced by source organs and the efficiency with which assimilates are partitioned to reproductive sinks (Mohanty *et al.,* 2017). Consequently, appropriate fertilizer management plays a critical role in enhancing growth and productivity by improving photosynthetic efficiency and assimilate allocation. Numerous studies have demonstrated that fertilizer application significantly influences plant physiological functioning and yield enhancement in major commercial crops such as maize, wheat and rice (Scharf *et al.,* 2002; Jiang *et al.,* 2004; Stewart *et al.,* 2005). In soybean, optimized nutrient management plays a critical role in enhancing physiological efficiency by improving nutrient availability, leaf area development, chlorophyll synthesis and enzymatic activity, thereby sustaining higher photosynthetic rates and improved plant water relations. In addition, the successful development and adoption of superior varieties are fundamental to achieving sustained increases in crop yield and grain quality (Lv *et al.,* 2020). Varietal differences in nutrient uptake efficiency, stress tolerance and physiological adaptability further influence crop responses to fertilizer regimes under varying environmental conditions. Hence, integrating appropriate fertilizer management with suitable varietal selection is essential to exploit the physiological potential of soybean for enhanced productivity.

The field experiment was conducted during the *kharif* season of 2024–25 at the Experimental Farm of the Department of Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani. The experiment was laid out in a split-plot design with three replications. Fertilizer management levels constituted the main-plot treatments, comprising 100% recommended dose of fertilizer (RDF), 75% RDF, 50% RDF and vermicompost at 5 t ha^{-1}, while three soybean varieties (MAUS 725, MAUS 612 and MAUS 158) were assigned to the subplots. Sowing was carried out at a spacing of 45 cm × 5 cm using a seed rate of 70 kg ha^{-1} during the 26th Standard Meteorological Week (SMW) of 2024 (1stJuly 2024). Grain and straw yields were recorded in kg ha^{-1}, while key gas exchange parameters, including photosynthetic rate (µmol m^{-2} s^{-1}) and stomatal conductance (mmol m^{-2} s^{-1}), were measured periodically at six distinct phenological stages using a portable infrared gas analyser (IRGA). All collected data were subjected to analysis of variance (ANOVA) appropriate for a split-plot design. Treatment means were compared using the least significant difference (LSD) test at the 5% level of significance.

Effect on grain and straw yield

The effect of fertilizer management treatments and soybean varieties on grain and straw yield of soybean, (Table 1) was statistically significant. Among the fertilizer management treatments, application of 100% RDF recorded the highest grain

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yield (2511.1 kg ha^{-1}) and straw yield (3140.4 kg ha^{-1}), which was significantly superior to 75% RDF, 50% RDF and vermicompost. These results are in agreement with the findings of Shinde *et al.,* (2015), who reported that application of 100% RDF was the most effective and optimal treatment for enhancing soybean productivity compared to 75% and 50% RDF. A progressive decline in both grain and straw yields was observed with reduction in fertilizer levels, with the lowest grain (1869.1 kg ha^{-1}) and straw yield (2398.1 kg ha^{-1}) recorded under vermicompost application alone. With respect to varietal performance, MAUS 612 produced significantly higher grain yield (2428.2 kg ha^{-1}) and straw yield (2987.5 kg ha^{-1}) compared to MAUS 725 and MAUS 158, whereas MAUS 158 recorded the lowest yields, indicating comparatively poorer yield potential under the prevailing agro-climatic conditions.

Table 1: Influence of fertilizer management practices and varietal differences on grain and straw yield of soybean

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Fertilizers management		
100% RDF	2511.1	3140.4
75% RDF	2215.4	2774.1
50% RDF	1944.6	2694.6
Vermicompost (5 t/ha)	1869.1	2398.1
S.E m±	85.15	102.24
C.D at 5%	294.68	353.81
Varieties		
MAUS 725	2091.7	2745.4
MAUS 612	2428.2	2987.5
MAUS 158	1885.1	2522.5
S.E m±	82.3	80.36
C.D at 5%	246.77	240.95
Interaction		
S.E m±	164.61	160.73
C.D at 5%	NS	NS

Effect on photosynthetic rate and stomatal conductance

The photosynthetic rate and stomatal conductance of soybean were significantly influenced by fertilizer management levels and varietal differences at all phenological stages (Table 2 and 3). The crop exhibited a progressive increase in photosynthetic activity and stomatal conductance from the vegetative stage to pod formation, followed by a gradual decline during pod development, grain filling and maturity, reflecting age-related senescence and reduced metabolic activity. Among the fertilizer management treatments, application of 100% RDF recorded the highest photosynthetic rate across all phenological stages. The maximum photosynthetic rate was observed at the pod formation stage (33.4 µmol m^{-2} s^{-1}), followed by pod development (25.0 µmol m^{-2} s^{-1}). A gradual reduction in photosynthetic rate was noted with decreasing fertilizer levels, with the lowest values recorded under vermicompost application, particularly at grain filling and maturity stages. The differences among fertilizer treatments were statistically significant, as indicated by the CD values at the 5% level.

A similar trend was observed for stomatal conductance, where 100 % RDF recorded significantly higher values at all growth stages, reaching a peak during pod formation (7,659.0 mmol m^{-2} s^{-1}). Reduced fertilizer availability under 75 % RDF and 50 % RDF resulted in a marked decline in stomatal conductance, while the lowest values were observed under vermicompost treatment. Higher stomatal conductance under adequate fertilizer supply can be attributed to improved leaf turgidity, nutrient availability and enhanced gas exchange capacity, which directly supports higher photosynthetic rates.

Among the soybean varieties, MAUS 612 exhibited superior physiological performance, recording the highest photosynthetic rate across most phenological stages, particularly during pod formation (31.1 µmol m^{-2} s^{-1}) and pod development (21.8 µmol m^{-2} s^{-1}). This variety also maintained higher stomatal conductance throughout the crop growth period, indicating better stomatal regulation and photosynthetic efficiency. MAUS 725 showed moderate performance, while MAUS 158 consistently recorded lower photosynthetic rate and stomatal conductance, especially during grain filling and maturity stages. Previous studies have reported that soybean photosynthetic rates vary with genetic variation accounting for a substantial proportion of differences in mesophyll conductance and related photosynthetic traits (Tomeo & Rosenthal, 2017). Long-term evaluations have further demonstrated consistent genetic gains in photosynthetic performance, including improvements in net photosynthesis, stomatal conductance and chlorophyll content (Liu *et al.,* 2012).

The observed enhancement in photosynthetic rate and stomatal conductance under adequate fertilizer supply is consistent with the findings of Pohare *et al.,* (2018) who reported that key physiological parameters of soybean, including photosynthetic rate and stomatal conductance, were significantly highest under 100% RDF. Adequate nutrient supply has further been shown to maintain stomatal function, optimizing the balance between carbon assimilation and water use (Flexas *et al.,* 2006). Overall, the combined analysis of photosynthetic rate and stomatal conductance clearly demonstrates a strong physiological linkage between nutrient availability, stomatal behaviour and photosynthetic efficiency in soybean. Adequate fertilizer application (100% RDF) enhanced stomatal conductance, facilitating greater CO_2 diffusion and assimilation, which in turn sustained higher photosynthetic rates during critical growth stages. The superior performance of MAUS 612 indicates its greater adaptability to the prevailing agro-climatic conditions and more efficient utilization of applied nutrients.

The results clearly indicate that optimal fertilizer application coupled with the selection of high-performing varieties is essential for improving photosynthetic efficiency, stomatal function, biomass accumulation and overall yield potential in soybean. These findings provide valuable insights for resource-use efficient and high-yield soybean production under the studied agro-ecological conditions.

Table 2: Variation in photosynthetic rate (µmol m^{-2} s^{-1}) of soybean across growth stages under different fertilizer levels and varieties

Treatments	Vegetative	Flowering	Pod Formation	Pod development	Grain filling	At maturity
Fertilizers management						
100% RDF	8.0	14.7	33.4	25.0	15.5	10.6
75% RDF	7.4	13.5	31.9	21.2	14.5	9.5
50% RDF	7.0	13.5	29.0	19.9	13.2	9.1
Vermicompost (5 t/ha)	6.5	12.6	25.4	18.8	12.2	8.4
SE(d)	0.09	0.15	0.14	0.26	0.12	0.13
CD	0.23	0.37	0.35	0.65	0.31	0.33
Varieties						
MAUS 725	7.2	13.6	29.5	20.9	13.9	9.4
MAUS 612	7.9	13.8	31.1	21.8	14.3	9.6
MAUS 158	6.6	13.4	29.2	21.1	13.3	9.2
SE(d)	0.06	0.13	0.40	0.23	0.16	0.09
CD	0.12	0.27	0.85	0.49	0.34	0.20

Table 3: Variation in stomatal conductance (mmol m^{-2} s^{-1}) of soybean across growth stages as influenced by fertilizer levels and varieties

Treatments	Vegetative	Flowering	Pod Formation	Pod development	Grain filling	At maturity
Fertilizers management						
100% RDF	348.9	4713.0	7,659.0	4,248.3	2,863.4	773.8
75% RDF	301.6	4629.4	6,710.5	4,464.7	2,469.6	715.4
50% RDF	255.6	3574.8	5,972.3	4,424.5	1,898.1	653.2
Vermicompost (5 t/ha)	232.1	3285.1	5,141.8	4,149.6	1,282.4	588.8
SE(d)	2.47	31.25	32.74	51.67	26.00	7.45
CD	6.17	77.95	81.67	128.89	64.86	18.60
Varieties						
MAUS 725	281.5	3,742.6	6,392.7	4,226.8	2,199.2	687.4
MAUS 612	308.4	3,867.8	6,688.7	4,413.7	2,284.5	700.0
MAUS 158	263.7	3,666.4	6,031.3	4,324.9	1,901.4	660.9
SE(d)	3.43	34.50	93.42	51.67	21.09	7.89
CD	7.33	73.77	199.74	128.89	45.09	16.87

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