Journal for Research in Applied Sciences and Biotechnology
www.jrasb.com

ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
https://doi.org/10.55544/jrasb.2.5.23

Response of Soybean to Nitrogen Levels and Weed Management on Growth, Yield and Economic Efficiency

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www.jrasb.com || Vol. 2 No. 5 (2023): October Issue

Received: 04-11-2023	**Revised:** 08-11-2023	**Accepted:** 11-11-2023

ABSTRACT

A field experiment was conducted during 2021 at the farm of Afghanistan National Agricultural Science and Technology University (ANASTU) to find out the suitable Response of Soybean to Nitrogen Levels and Weed Management on growth, yield and economic efficiency, the experimental design was Split plot design with two factors replicated thrice, the experiment consist of three weed management methods (Un-weeded check, Pendimethalin + hand weeding and Pendimethalin + Imazethapyr) and four nitrogen levels (Control, 40 kg N/ha, 60 kg N/ha and 80 kg N/ha). The maximum growth, yield and economic efficiency was in treatment (Pendimethalin + Imazethapyr), Root dry weight (9.42/plant), Nodules/plant (25.5),Nodes/plant (25.57, 27.68), Internodes distance(36.88 mm), Pods/plant(41.1), Seeds/pod (2.5), 1000 seed weight (102.5 gr), Grain yield (2.20 ton/ha), Gross Returns (187.863 AFN/ha), Net Returns (134.308 AFN/ha) and Benefit: cost ratio (2.504) compared to Un-weeded check and Pendimethalin + hand weeding, Root dry weight (9.67g/plant), Nodules/plant (25.6), Nodes/plant (27.68), Internodes distance(37.99 mm), Pods/plant(45.3), Seeds/pod (2.5), 1000 seed weight (104.7gr), Grain yield (2.20 ton/ha), Gross Returns (187.922 AFN/ha), Net Returns (133.159 AFN/ha) compared to 60 kg N/ha, 40 kg N/ha and control. it can be concluded that the application of (Pendimethalin + Imazethapyr) along with 80 kg N/ha was found to be suitable for profitable cultivation of soybean with optimum quality under the agro-climatic conditions of Kandahar Afghanistan.

Keywords- economic efficiency, growth, Nitrogen, Soybean, weed, yield.

I. INTRODUCTION

Soybean (*Glycine max*) is most important oilseed crop for human beings, animals and the biodiesel industry due to its high contents of oil (19%) and protein (40%) (*Mon et al., 2017*). Physiologically, soybean's growth has a high nitrogen (N) demand that is required mainly for protein synthesis. For example, a maximal daily uptake of 4.6 kg ha^{-1} is required at the R4 (full pod) stage (*Bender et al., 2015*) and approximately 300 kg N is needed to produce 3 t ha^{-1} of soybean (*Youn et al., 2009*). In an environment that is ideal for crop's growth, especially for soybean, biological nitrogen fixation (BNF) can fulfil 50% of soybean's total N demand (*Bender et al., 2015*). However, high soil NO3, low moisture, low pH, compaction, acidity or drought can inhibit soybean's BNF process, growth and yield production (*Mourtzinis et al., 2018*). The present 0.6 to 1.2 t ha^{-1} productivity in Afghanistan is substantially low compared to the global 2.77 t ha^{-1} productivity (*NEI, 2017*). Productivity in Afghanistan is substantially low compared to the global 2.77 t ha^{-1} productivity (*NEI, 2017*). It is most likely due

ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
https://doi.org/10.55544/jrasb.2.5.23

to the lack of indigenous N fixing bacteria and soil residual N, without rhizobia inoculation, excessive or inappropriate N application and low soil fertility in Afghanistan. N fertilizer has to be supplied to promote soybean growth and productivity. Furthermore, overuse of NO3 has always resulted in leaching or de nitrification. Even if N was applied as a basal application, plant roots could not possibly absorb all of them at once. In such soil conditions, N fertilization should be carefully managed throughout the crop growth cycle. One of the effective methods of N fertilization management is split application by adjusting the timing of fertilizer application within the plant growth stage. The fertilizer split can also improve the efficiency of crop uptake, re-translocation, and nitrogen use efficiency (*Khan et al., 2017*).

Positive response of different rates and time of N fertilization on soybean's growth, nutrient uptake and seed yield have been studied. For example, fertilization of 30 kg N ha^{-1} or 7.5 mM pot^{-1} as a basal application and at the beginning of flowering (R1) stage increased plant height, leaf area index (LAI), dry matter accumulation and seed yield (*Singh and Singh 2013; Bhangu and Virk, 2019; Zhou et al., 2019*).

The supply of 100, 50, 40, 30 or 10 kg N ha^{-1} as basal, at 25 DAS (days after sowing), the R1, pod initiation (R3) and beginning of seed (R5) stages significantly increased the soybean's aboveground biomass and seed yield (*Gan et al., 2002*). The various grassy and broad leaf weeds emerge simultaneously with the crop plants and compete for essential nutrients, moisture, sunlight and space, causing substantial loss in yield (35-55%), depending on the types of weed flora and density (*Kewat et al. 2000, Singh 2007*).

Weed management is another important aspect as weeds are one of the most limiting factors for rapid crop growth. Soybean yield losses resulting from weed interference and cost of weed control constitute some of the highest costs involved in the crop production. Approximately, the monetary losses due to weeds in the recent years have averaged about 17% of the crop value. Natural weed populations in most fields are high enough to cause devastating yield losses if left uncontrolled. The yield losses between 50 to 90% are common for soybean grown in un-weeded populations. Weeds compete directly with soybean for light, nutrients (especially N) and moisture and interference indirectly through the production and release of allopathic chemicals which inhibit crop growth. Fertilization, although perhaps not as effective as a direct weed control tactic but is important indirectly. The properly fertilized soybean crop will become competitive with weeds at an earlier stage than a poorly fertilized crop. Chlorophyll content in plants depends on soil N availability and crop N uptake, which are important management factors in arable farming for enhancing weed competitive attributes (*De Silva et al., 2013)*. The objective of the study was to evaluate nitrogen effects and weed management growth, yield and economic efficiency.

II. MATERIALS AND METHODS

The experiment was conducted during cropping season of 2021 at the Farm of Afghanistan National Agricultural Science and Technology University (ANASTU) in Kandahar, Afghanistan to evaluate response of soybean to the different levels of nitrogen and weed management on growth, yield and economic efficiency. The experiment site was clay loan in soil texture, alkaline in reaction (7.9), medium in organic carbon (0.46 %), low in available nitrogen (87.85 kg/ha). low available phosphorus (9.60 kg/ha), high available potassium (234.3 kg/ha). The experiment laid out in Split plot design with two factors replicated thrice with twelve treatments *viz.*, T_1 (W1N1: Un-weeded check + 0 kg N/ha), T_2 (W1N2: Un-weeded check+40 kg N/ha), T3 (W1N3: Un-weeded check +60 kg N/ha), T4 (W1N4:Un-weeded check+80 kg/ha), T5 (W2N1: Pendimethalin 1 kg/ha followed by 1 hand weeding+0 kg N/ha), T6 (W2N2: Pendimethalin 1 kg/ha followed by 1 hand weeding+40 kg N/ha), T7 (W2N3: Pendimethalin 1 kg/ha followed by 1 hand weeding+60 kg N/ha), T8 (W2N4: Pendimethalin 1kg/ha followed by 1 hand weeding+80 kg N/ha), T9 (W3N1: Pendimethalin 1kg/ha followed Imazethapyr 100 g/ha+0 kg N/ha), T10 (W3N2: Pendimethalin 1kg/ha followed Imazethapyr 100 g/ha+40 kg N/ha), T11 (W3N3: Pendimethalin 1 kg/ha followed Imazethapyr 100 g/ha+60 kg N/ha), T12 (W3N4: Pendimethalin 1 kg/ha followed Imazethapyr 100 g/ha +80 kg N/ha).

The plot size was 4 m length×3 m width ($12m^2$). The plant spacing was 50 cm × 10 cm using seed rate of 80 kg/ha. One border row from both the sides of each plot was discarded, besides, 25 cm crop rows from other two sides as border effect. The freshly harvested, cleaned seeds of soybean cultivar stine-3400-2 were obtained from the URDOKHAN farm of Herat province. Soybean seeds were sown manually with 5 cm depth a spacing of 50×50 cm between row to row and 8 to 8 cm from plant to plant with in row and were covered with soil on 15th of March, 2021. In this experimentation fertilizers were applied from three different sources [P fertilizer through triple super phosphate (TSP, 46% P_2O_5), N fertilizer through urea (46% N) and K fertilizer through sulphate of potash (SOP, 50% K_2O). Other fertilizers were applied uniformly based on recommendations. The recommended dose of P and K at 60 and 40 kg/ha was applied to soybean crop.

The full dose of P and K were applied to all the plots across replication as basal at final land preparation/harrowing before seed drilling. The analysis of variance (one–way ANOVAs) was used to determine treatment effects. Standard error of means (SEm$\pm$) and least significant difference [LSD (p=0.05)] level of significance worked out for each parameter. All data analyzed by OPSTAT.

ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
https://doi.org/10.55544/jrasb.2.5.23

III. RESULT AND DISCUSSION

Effect of soybean to nitrogen levels and weed management on root dry weight, nodules/plant, nodes/plant and internodes distance

Nitrogen management practices significantly affected the root dry weight per plant at 30, 60 and 90 DAS. At 30 DAS, the application of 80 kg N/ha significantly recorded the highest root dry weight (0.27) followed by application 60 kg N/ha (0.25) and application of 40 kg N/ha (0.22). At 60 DAS, application of 80 kg N/ha significantly recorded the highest root dry weight (4.04) followed by application 60 kg N/ha (3.72) and application of 40 kg N/ha (3.46). At 90 DAS, the application of 80 kg N/ha significantly recorded the highest root dry weight (9.67) followed by application 60 kg N/ha (8.57) and application of 40 kg N/ha (7.40). The lowest root dry weight was recorded under control plots 0 kg N/ha during all the growth stages. A similar result was reported by *Yagoub et al., (2012*) and *Khaleeq et al., (2023b*). Weed management affected the root dry weight per plant was significantly at 30, 60, 90 DAS. At 30 DAS, pendimethalin+imazethapyr significantly recorded the highest root dry weight (0.26), followed by pendimethalin + hand weeding (0.24) and minimum under un-weeded check (0.21). At 60 DAS, pendimethalin + imazethapyr) significantly recorded the highest root dry weight (3.92) followed by pendimethalin+hand weeding) (3.55) and un-weeded check (3.30). At 90 DAS, (Pendimethalin+Imazethapyr) significantly recorded the highest root dry weight (9.42) followed by (Pendimethalin + hand weeding) (7.88) and Un-weeded check (6.76). A similar result was reported by *Deore et al., (2008*). Under field conditions, imazethapyr dissipates in the soil by microbial degradation and photolysis. Imidazolinone herbicides are generally weakly adsorbed by soil.

Thus, these are safe herbicides to be used under field conditions. Nitrogen management significantly influenced the nodules/plant at 30, 60 and 90 DAS. At 30 DAS, the application of 80 kg N/ha significantly recorded the highest nodules/plant (7.0) followed by application 60 kg N/ha (6.7) and 40 kg N/ha (6.4). At 60 DAS, application of 80 kg N/ha significantly recorded the highest nodules/plant (26.4) followed by application of 60 kg N/ha (25.4) and application of 40 kg N/ha (24.3). At 90 DAS, application of 80 kg N/ha significantly recorded the highest nodules/plant (26.6) followed by application 60 kg N/ha (25.7) and application of 40 kg N/ha (24.4). The lowest nodules/plant was recorded under control (0 kg N/ha) during all the growth stages. Weed management affected the root dry weight per plant was significantly at 30, 60, 90 DAS. At 30 DAS, pendimethalin + imazethapyr significantly recorded the highest nodules/plant (6.7) followed by pendimethalin + hand weeding (6.6) and minimum under un-weeded check (6.4). At 60 DAS, pendimethalin + imazethapyr significantly recorded the highest nodules/plant (25.6) followed by pendimethalin + hand weeding (24.6) and un-weeded check (24.0). At 90 DAS, pendimethalin + imazethapyr significantly recorded the highest nodules/plant (25.5) followed by pendimethalin+hand weeding (24.7) and minimum un-weeded check (24.4).

A similar result was reported by *Kalhapure et al., (2011)* reported enhancement of growth and yield attributing character of soybean with pre-emergence application of pendimethalin and postemergence application of imazetahpyr with effective weed control in soybean. The higher nodules with higher N Rate a similar result was reported by *Saxena et al., (2003)*. Nitrogen management also significantly influenced the nodes/plant and internodes distance in all growth stages. The application of 80 kg N/ha significantly recorded the highest nodes/plant and internodes distance (27.68) and (37.99) followed by application 60 kg N/ha (25.94) and (35.89) and application of 40 kg N/ha (24.24) and (34.36). The lowest nodes/plant and internodes distance was recorded under control (0 kg N/ha) during all the growth stages. Data showed weed management significantly influenced nodes/plant and internodes distance at all growth stages of soybean. At harvest stage pendimethalin + imazethapyr significantly recorded the highest nodes/plant and internodes distance (25.57) and (36.88), followed by pendimethalin + hand weeding (25.57) and (35.74) in un-weeded check (23.82) and (32.9) respectively. A similar result was reported *Saito et al., (2014)* showed the application of combined nitrogen, especially nitrate, to soybean plants is known to strongly inhibit nodule formation, growth and nitrogen fixation. Therefore, a non-significant increase in nodes per plant was recorded with 80 kg N/ha over 60 kg N/ha. *Kalhapure et al., (2011)* have also reported a higher nodes and better plant growth with appropriate weed management protocols including herbicides.

Table (1): Effect of Soybean to Nitrogen levels and weed Management on Root dry weight, Nodules/plant, Nodes/plant and Internodes distance

Treatments	Root dry weight (g/plant)			Nodules/plant			Nodes/ plant	Internodes distance
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS		
Weed management								
Un-weeded check	0.21	3.30	6.76	6.4	24.0	24.4	23.82	32.95
Pendimethalin + hand weeding	0.24	3.55	7.88	6.6	24.6	24.7	25.55	35.74

ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
https://doi.org/10.55544/jrasb.2.5.23

Pendimethalin + Imazethapyr	0.26	3.92	9.42	6.7	25.6	25.5	25.57	36.88
SEm±	0.01	0.07	0.19	0.04	0.19	0.27	0.25	0.09
CD (≤0.05)	0.02	0.29	0.75	0.17	0.78	NS	1.0	0.35
Nitrogen management								
Control	0.196	3.14	6.43	6.1	22.7	23.0	22.07	32.54
40 kg N/ha	0.221	3.46	7.40	6.4	24.3	24.4	24.24	34.36
60 kg N/ha	0.247	3.72	8.57	6.7	25.4	25.7	25.94	35.88
80 kg N/ha	0.268	4.04	9.67	7.0	26.4	26.6	27.68	37.99
SEm±	0.003	0.03	0.13	0.02	0.09	0.08	0.300	0.15
CD (≤0.05)	0.009	0.08	0.38	0.06	0.27	0.22	0.90	0.46

DAS= Days after Sowing

Response of Soybean to Nitrogen levels and Weed management on yield attributes, yield and economic efficiency

Nitrogen management significantly influenced the number of pods/plant at harvest stage. The application of 80 kg N/ha significantly recorded the highest number of pods (45.3 pods/plant) followed by 60 kg N/ha (42.2 pods/plant) and 40 kg N/ha (35.6 pods/plant). The lowest number of pods (30.2 pods/plant) was recorded under control plots 0 kg N/ha. The different weed management significantly influenced the number of pods/plant during the harvest stages. At harvest stage, application of pendimethalin+imazethapyr significantly recorded the highest number of pods (41.1 pods/plant) followed by pendimethalin+hand weeding (38.6 pods/plant) and un-weeded check (35.3 pods/plant). A similar result was reported by *Warade et al., (2003)* reported that application of 40 kg N/ha significantly increased the number of pods, test weight, seed and straw yield of soybean over all other treatments. The increase in total source helps in increasing the total sink capacity and hence improve the yield attributes including pods per plant. Nitrogen management significantly influenced the number of seeds/pod at harvest stage. Application of 80 kg N/ha significantly recorded the highest number of seeds/pod (2.7 seeds/pod) followed by 60 kg N/ha (2.4seeds/pod) and 40 kg N/ha (2.2 seeds/pod). The lowest number of seeds/pod (2.1 seeds/pod) was recorded under control (0 kg N ha^{-1}) respectively. A similar result was reported by *Barker and Sawyer (2005)* found that nitrogen application to soybean even during the reproductive stage has potential to increase soybean productivity and plant N concentration. The even distribution of accumulated sink among the yield attributes with appropriate nitrogen management ensures higher yield. The different weed management significantly influenced the number of seeds/pod during the harvest stages. At harvest stage, pendimethalin+imazethapyr significantly recorded the highest number of seeds/pod (2.5 seeds/pod) followed by pendimethalin+hand weeding (2.4 seeds/pod) and un-weeded check (2.2 seeds/pod). A similar result was reported by *Abdelhamid and EI-Metwally (2008)* reported that two hand hoeing treatments gave the highest value of number of pods per plant, weight of pods per plant and number of seeds per plant by 140.7, 150.0, and 59.8% respectively, compared to the un-weeded treatment. Shaikh et al.,.have also observed that imazethapyr (early POE) @ 0.075 kg a.i./ha + one hoeing at 30 DAS was found to be significantly superior in case of seed (32.04 q/ha) and straw yields (44.84 q/ha) over the other integrated weed control treatment. Nitrogen management significantly influenced the 1000-seed weight (g) at harvest stage. Application of 80 kg N/ha significantly recorded the highest 1000-seed weight (g) (104.7 g) followed by 60 kg N/ha (99.6 g) and 40 kg N/ha (96.3 g). The lowest 1000-seed weight (g) (92.3 g) was recorded under control (0 kg N/ha). A similar result was reported by Lee and Yun (2006) and Sadiq et al (2023) studied that the increasing N supply in soybean increased seed yield per plant particularly in seed inoculated with Rhizobium and at the lower plant density. Seed yield significantly correlated with shoot dry weight, nodule number and plant N content. A higher seed weight due to higher nitrogen application can be attributed to higher biomass accumulation and timely partitioning among various yield attributes. The different weed management significantly influenced the 1000-seed weight (g) during the harvest stages. At harvest stage, pendimethalin + imazethapyr significantly recorded the highest 1000-seed weight (102.5 g) followed by pendimethalin + hand weeding (99.1 g) and un-weeded check (93.1 g). *Abdelhamid and EI-Metwally (2008)* reported that two hand hoeing treatments gave the highest value of number of pods per plant, weight of pods per plant and number of seeds per plant by 140.7, 150.0, and 59.8% respectively, compared to the un-weeded treatment. Data reflected that grain yield differed significantly due to different nitrogen levels. Application of 80 kg N/ha significantly recorded the highest seed yield (g) (2.20 t/ha) followed by 60 kg N/ha (2.05 t/ha) and 40 kg N/ha (1.19 t/ha). The lowest seed yield (1.71 t/ha) was recorded under control (0 kg N/ha).

ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
https://doi.org/10.55544/jrasb.2.5.23

A similar result was reported by *Bekele et al., (2016), Nazir et al., (2022)* and *Khaleeq et al., (2023a)* reported that the grain yield of soybean was significantly affected by main effect of soybean varieties and nitrogen rates. *Yield (842 kg/ha)* obtained from plot treated with 96 kg N/ha was significantly higher than that of 32 kg N/ha (586 kg/ha). Soybean yield enhanced by increased nitrogen rates, especially under nitrogen limited soils. Weed management practices led to significant difference in soybean yield. At harvest stage, pendimethalin+imazethapyr) significantly recorded the highest seed yield (2.20 t/ha) followed by pendimethalin+hand weeding (2.03 t/ha) and un-weeded check (1.65 t/ha). *Sangeetha et al., (2011)* have also concluded that early post-emergence application of imazethapyr @ 100 g/ha at 15 DAS with hand weeding at 45 DAS provided better weed control and resulted in increased yield compared to other weed control methods. Nitrogen management also significantly influenced the gross returns of soybean. The application of 80 kg N/ha significantly recorded the highest gross returns than 60 kg N/ha and which in turn was significantly better than 40 kg N/ha. The minimum gross returns (146.08 AFN/ha) was recorded under control plots (0 kg N/ha). Weed management significantly influenced the gross returns of soybean. After harvest, the treatment where pendimethalin +imazethapyr resulted in the highest gross returns (187.867AFN/ha), followed by pendimethalin + hand weeding (172.57 AFN/ha) and minimum was recorded in un-weeded check (143.64 AFN/ha) (Table 4.8). Nitrogen management also significantly influenced the net returns after harvest. The application of 80 kg N/ha significantly recorded the highest net returns over 60 kg N/ha and which in turn was significantly better than 40 kg N/ha. The lowest net returns (93.34 AFN/ha) was recorded under control plots (0 kg N/ha). Weed management significantly influenced the net returns also after soybean. After harvest, the application of pendimethalin +imazethapyr significantly recorded the highest net returns (134.31 AFN/ha) followed by pendimethalin + hand weeding (118.26 AFN/ha) and un-weeded check (89.58 AFN/ha) (Table 4.8). Nitrogen management also significantly influenced the benefit cost ratio at harvest. The application of 80 kg N/ha significantly recorded the highest benefit cost ratio over 60 kg N/ha and which in turn was significantly better than 40 kg N/ha. The lowest benefit cost ratio (1.770) was recorded under control plots (0 kg N/ha). Weed management significantly influenced the benefit: cost ratio of soybean after harvest.

After harvest, pendimethalin+imazethapyr significantly recorded the highest benefit cost ratio (2.504) followed by pendimethalin+hand weeding (2.174) and un-weeded check (1.655) (Table 4.8). Yadhav *et al*., (2009) and Hemmat et al., (2023) also noticed that the highest gross income (41822/ha), net return (21971.50/ha) and B: C ratio (2.11) under weed free condition followed by two hand weeding at 15 and 30 DAS (39198 and 20547/ha respectively). Peer *et al*., (2013) reported that pendimethalin @ 1.0 kg/ha integrated with one hand weeding at 35 DAS (critical period of weed removal) is the most appropriate method for effective weed management and profitable cultivation of soybean.

Table (2): Response of Soybean to weed management and Nitrogen levels on yield attributes, yield and economic efficiency

Treatments	Pods/plant	Seed/pod	1000 seed weight	Grain yield (ton/ha)	Gross Returns (AFN/ha)	Net Returns (AFN/ha)	Benefit: cost ratio
Weed management							
Un-weeded check	35.3	2.2	93.1	1.65	143.643	89.575	1.655
Pendimethalin + hand weeding	38.6	2.4	99.1	2.03	172.568	118.260	2.174
Pendimethalin + Imazethapyr	41.1	2.5	102.5	2.20	187.863	134.308	2.504
SEm±	0.25	0.04	1.16	0.21	1.163	1.165	0.022
CD (≤0.05)	1.03	0.15	4.67	0.88	4.688	4.698	0.087
Nitrogen management							
Control	30.2	2.04	92.3	1.71	146.082	93.336	1.770
40 kg N/ha	35.6	2.2	96.3	1.19	162.098	108.098	2.000
60 kg N/ha	42.2	2.4	99.6	2.05	175.994	121.598	2.238
80 kg N/ha	45.3	2.7	104.7	2.20	187.922	133.159	2.437
SEm±	0.61	0.04	0.55	0.12	1.973	1.973	0.037
CD (≤0.05)	1.82	0.11	1.63	0.63	5.908	5.908	0.110

ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
https://doi.org/10.55544/jrasb.2.5.23

IV. CONCLUSION

The present study has provided valuable insights into the effects of nitrogen levels and weed management on soybean growth, yield, and economic efficiency. The results indicated that the combination of 80 kg N/ha along with Pendimethalin+Imazethapyr is the most effective treatment for achieving optimal soybean production. This finding has important implications for farmers and researchers seeking to improve soybean cultivation practices. Overall, this research contributes to a better understanding of the complex interactions between nitrogen levels, weed management and soybean growth and yield, and highlights the importance of adopting effective management strategies to maximize crop productivity and economic returns. Further research is needed to explore the long-term effects of these treatments on soil health and sustainability as well as to investigate the potential for integrating other management practices such as crop rotation and intercropping to further enhance soybean production.

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ISSN: 2583-4053
Volume-2 Issue-5 || October 2023 || PP. 139-145
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