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Effect of Different Soil Amendments on Growth, Yield, and Yield Components of Mung bean (*Vigna radiata* L.) Variety 08 Zudrus

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ABSTRACT: This study was conducted from May–September 2025 / the 2025 growing season at the Research Farm of the Department of Agronomy, Faculty of Agriculture, Kabul University, to evaluate the effects of organic and inorganic fertilizers on the growth, yield, and yield components of mung bean (*Vigna radiata* L.) variety 08 Zudrus. The experiment was arranged in a randomized complete block design (RCBD) with four treatments with three replications. Treatments included a control, NPK fertilizer, XiR Biomass containing 10% humic acid, and XiR Biomass containing 20% humic acid. Data on growth, yield components, and yield parameters were analyzed using STAR software (version 2.0.1) through analysis of variance (ANOVA) at the 5% significance level. Fertilizer treatments significantly influenced several growth and yield traits. XiR Biomass containing 20% humic acid produced the tallest plants (35.10 cm), the highest number of pods per plant (10.53), and the greatest biological yield (7851.63 kg ha^{-1}), whereas XiR Biomass containing 10% humic acid produced the highest grain yield (2202.38 kg ha^{-1}) and number of grains per pod (11.00). In contrast, tiller number, branch number, pod length, pod width, and 100-seed weight were not significantly affected. Overall, XiR Biomass organic fertilizers showed greater potential than NPK fertilizer for improving mung bean growth and productivity under the agro-ecological conditions of Kabul.

KEYWORDS: Mung bean, organic fertilizer, NPK fertilizer, growth, yield.

INTRODUCTION

Mung bean (*Vigna radiata* L.), commonly known as green gram, is an important short-duration legume crop belonging to the family Fabaceae and is widely cultivated across tropical and subtropical regions. It is valued for its high nutritional quality, adaptability to marginal environments, and its role in improving soil fertility through biological nitrogen fixation. The crop is believed to have originated in South Asia and has since spread to different parts of Asia, Africa, and Australia due to its ability to perform well under diverse agro-ecological conditions, particularly in semi-arid and rainfed farming systems (Shil & Bandopadhyay, 2007; Choudhary et al., 2015; Pooniya et al., 2015). Its short growth duration, usually between 70 and 120 days, makes it highly suitable for inclusion in multiple cropping systems, especially as a catch or rotation crop with cereals such as wheat and rice.

Nutritionally, mung bean is an important source of plant-based protein, containing approximately 24–26% protein, along with carbohydrates, essential minerals, vitamins, and bioactive compounds. It plays a significant role in addressing protein deficiency and malnutrition in developing countries where cereal-based diets dominate (Khan et al., 2017a; Hussain et al., 2011). The seeds are consumed in whole, split, or sprouted form, with sprouts being particularly valued for their high vitamin content and digestibility. In addition, mung bean contains bioactive compounds such as isoflavones that have been associated with antioxidant, antimicrobial, and health-promoting properties (Dzudie & Hardy, 1996; Pookpakdi & Pataradilok, 1993). These characteristics have increased its demand both as a food and functional crop in domestic and international markets.

Globally, mung bean production is concentrated mainly in Asia, where countries such as India, China, Pakistan, Bangladesh, Thailand, and Vietnam account for the majority of cultivation and production. Outside Asia, it is grown in smaller areas of Africa and Australia, where it is increasingly recognized for its drought tolerance and low input requirements (Chauhan & Williams, 2018). Despite its wide adaptability, productivity remains relatively low compared to its genetic potential, largely due to inadequate agronomic practices, poor soil fertility, and limited adoption of improved technologies. In many developing regions, including Afghanistan, yields remain below 1 ton ha^{-1}, reflecting a significant yield gap between research stations and farmers' fields (FAO, 2016; Hamim, 2016).

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In Afghanistan, mung bean is an important pulse crop cultivated in warmer and irrigated regions as part of smallholder farming systems. It is often grown alongside cereals or as a rotational crop to improve soil fertility and diversify farm income. However, its productivity is constrained by several biophysical and socio-economic factors, including low soil fertility, moisture stress, limited access to improved varieties, and inadequate nutrient management practices (Erskine & Nesbitt, 2009; Jalali et al., 2017). Farmers commonly rely on traditional practices with minimal fertilizer application due to economic constraints and limited awareness of balanced nutrient management. These limitations result in low yield levels and unstable production across seasons.

Soil fertility is one of the most critical factors affecting mung bean growth and productivity. Many agricultural soils in Afghanistan are characterized by low organic matter, nitrogen, and phosphorus content, which directly limits plant growth and yield potential. Mung bean, although capable of fixing atmospheric nitrogen through symbiosis with Rhizobium bacteria, still requires adequate soil nutrient availability particularly phosphorus for effective nodulation, root development, and energy transfer processes (Amanullah et al., 2012; Khan et al., 2014). Phosphorus deficiency is widely recognized as a major constraint in legume production, leading to poor root growth, reduced nodulation, delayed flowering, and lower seed yield. Similarly, potassium and micronutrients such as zinc and boron are essential for physiological functions, including enzyme activation, reproductive development, and stress tolerance (Praveena et al., 2018; Yadav et al., 2017).

Nitrogen plays a vital role in vegetative growth, chlorophyll formation, and protein synthesis. Although biological nitrogen fixation reduces the need for external nitrogen inputs, starter nitrogen application can enhance early growth, especially in low-fertility soils. However, excessive nitrogen can suppress nodulation, highlighting the importance of balanced nutrient management (Sultana et al., 2009; Mandal & Sikdar, 1999). Therefore, integrating biological nitrogen fixation with appropriate fertilizer management is essential for achieving optimal growth and yield.

In addition to chemical fertilizers, organic amendments such as farmyard manure, poultry manure, vermicompost, and compost significantly contribute to improving soil physical, chemical, and biological properties. These amendments enhance soil structure, increase water-holding capacity, and improve microbial activity, thereby supporting better root development and nutrient uptake (Baghlani et al., 2023; Hosen, 2021). Poultry manure, in particular, provides readily available nutrients that enhance vegetative growth and yield components, while vermicompost improves nutrient availability and soil biological activity. Green manuring and crop residue incorporation further enhance soil organic matter and long-term fertility.

Biochar has also emerged as an important soil amendment due to its ability to improve nutrient retention, soil structure, and water-holding capacity. Its porous nature provides a favorable habitat for soil microorganisms and enhances nutrient use efficiency, particularly in degraded or low-fertility soils (Lehmann et al., 2003; Steiner et al., 2007). In addition, biofertilizers such as Rhizobium, phosphate-solubilizing bacteria, and plant growth-promoting rhizobacteria enhance nutrient availability and biological nitrogen fixation, leading to improved crop growth and yield (Bam et al., 2022; Yousefi et al., 2025).

Integrated Nutrient Management (INM), which combines organic, inorganic, and biological sources of nutrients, is considered a sustainable strategy for improving crop productivity and maintaining soil health. INM enhances nutrient use efficiency, reduces dependence on chemical fertilizers, and promotes long-term soil fertility by maintaining organic matter and microbial activity (Moe et al., 2019; Ikram Ullah et al., 2023). This approach is particularly relevant for resource-poor farming systems where farmers face constraints in accessing chemical fertilizers and other inputs.

Despite extensive global research on mung bean agronomy and nutrient management, there remains a significant research gap in Afghanistan, particularly regarding the integrated use of soil amendments under local agro-ecological conditions. Most existing studies have focused on either chemical fertilizers or organic amendments in isolation, with limited attention to their combined effects on growth, yield, and soil fertility. Furthermore, limited research has been conducted on improved mung bean varieties under integrated nutrient management systems in Afghan conditions. One such improved variety is Zudrus 08, which has shown promising potential; however, its response to different nutrient management practices has not been thoroughly evaluated under local field conditions.

Therefore, this study was conducted to evaluate the effects of different soil amendments on the growth, yield, and yield components of mung bean (*Vigna radiata* L.) variety Zudrus 08. The study also aimed to assess how different nutrient management strategies influence plant growth parameters, yield attributes, and overall productivity under field conditions. By integrating organic, inorganic, and biological nutrient sources, this research seeks to generate location-specific recommendations that can enhance mung bean productivity, improve soil fertility, and support sustainable agricultural production systems in Afghanistan.

MATERIALS AND METHODS

Study Site

The experiment was conducted during the 2025 growing season at the Research Farm of the Faculty of Agriculture, Kabul University, Afghanistan (34.31° N, 69.08° E; 1,809 m above sea level). The experimental site has a semi-arid climate. Before sowing, composite soil samples (0–30 cm depth) were collected and analyzed to determine the initial soil properties. The experimental soil was sandy loam, slightly alkaline (pH 7.8), and low in organic matter (0.9%), total nitrogen (0.03%), and available phosphorus (1.83 ppm).

Experimental Design and Treatments

The experiment was arranged in a randomized complete block design (RCBD) with four fertilizer treatments and three replications. The treatments consisted of:

- **T_1:** Control (received the common FYM and nitrogen application, but no additional NPK or Xir Biomass).
- **T_2:** NPK fertilizer (100:100:60)
- **T_3:** Xir biomass OF1 containing 10% humic acid, applied at 1,000 kg ha^{-1}
- **T_4:** Xir biomass OF2 containing 20% humic acid, applied at 500 kg ha^{-1}

The application rates of OF1 and OF2 were selected so that both treatments supplied an equivalent nominal amount of humic acid, approximately 100 kg humic acid ha^{-1}.

Each experimental plot measured 2 m × 2 m, giving a plot area of 4 m^2. Adjacent plots and blocks were separated by appropriate buffer spaces to minimize interference among treatments.

The mung bean (*Vigna radiata* L.) variety 08zudruss was sown on 25 May 2025 at a seed rate of 25 kg ha^{-1}. Seeds were planted at a spacing of 30 cm between rows and 10 cm between plants.

Crop Management

The respective fertilizer treatments were applied according to the assigned treatment and incorporated into the soil during land preparation. XiR Biomass OF1 was applied at 1,000 kg ha^{-1}, whereas XiR Biomass OF2 was applied at 500 kg ha^{-1}. The NPK fertilizer was applied to the plots assigned to the NPK treatment at the recommended rate.

In addition, the recommended rate of nitrogen fertilizer was applied uniformly to all treatments in two equal splits to minimize nitrogen deficiency. Well-decomposed farmyard manure and the recommended nitrogen application were applied uniformly to all treatments as common basal management. Nitrogen was applied in two equal splits. Therefore, the Control treatment received the common FYM and nitrogen application but did not receive additional NPK or Xir Biomass fertilizer. The other treatments received their respective NPK or Xir Biomass amendments in addition to the common basal management.

All other agronomic practices, including irrigation, thinning, hand weeding, and pest management, were carried out uniformly across treatments according to standard mung bean production practices.

Data Collection

Data were collected from randomly selected representative plants within each plot. Growth parameters included plant height (cm), number of branches per plant, and number of leaves per plant. Yield components included number of pods per plant, number of seeds per pod, and 100-seed weight (g). The crop was harvested at physiological maturity in two pickings. Grain yield was determined from the net harvested area of each plot and converted to kilograms per hectare (kg ha^{-1}).

Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) appropriate for a randomized complete block design to determine the effects of different soil amendment treatments on mung bean growth, yield, and yield components. When the overall treatment effect was significant, treatment means were separated using the Least Significant Difference (LSD) test at the 5% probability level ($p \leq 0.05$). Individual plants sampled within a plot were treated as subsamples, and their plot mean, rather than individual plants, constituted the experimental unit. Statistical analyses were performed using STAR software.

Harvest index was calculated independently for each experimental plot as:

$$HI\ (\%) = (\text{grain yield} / \text{total above-ground biological yield}) \times 100.$$

The resulting plot-level harvest-index values were then subjected to the same RCBD analysis used for the other response variables.

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RESULTS

Vegetative Growth

Plant height was significantly affected by fertilizer treatments (ANOVA, $p < 0.05$). The tallest plants were recorded under OF2 (35.1 cm), which was statistically superior and grouped under significance letter "a". This indicates that OF2 had a stronger effect on vegetative growth compared to the other treatments under the experimental conditions. OF1 produced a plant height of 28.73 cm and was categorized as "b", showing no significant difference from the Control (29.67 cm) and NPK fertilizer (28.2 cm), which were also grouped under the same significance level. Overall, OF2 clearly enhanced plant height compared to the remaining treatments, while OF1, Control, and NPK showed relatively similar performance (Table 1).

Table 1. Plant height (cm)

Treatments	Plant height (cm)
Control	29.67 b
NPK Fertilizer (100:100:60)	28.2 b
Xir biomass 10% humic acid	28.73 b
Xir biomass 20 humic acid	35.1 a
CV (%)	-
ANOVA	*

The number of tillers per plant showed no significant differences among fertilizer treatments (ANOVA, $p > 0.05$). Although minor numerical variations were observed, these were not statistically meaningful, indicating that tiller production remained relatively stable across all treatments.

Similarly, the number of branches per plant was not significantly affected by fertilizer application (ANOVA, $p > 0.05$). However, numerical differences were recorded, with OF2 producing the highest number of branches (4.37), followed by OF1 (3.9), Control (3.6), and NPK fertilizer (3.1). Despite these variations, statistical analysis confirmed that fertilizer treatments did not significantly influence branching.

The number of leaves per plant also showed no significant differences among treatments ($p > 0.05$). OF2 recorded the highest leaf number (6.27), followed by OF1, Control, and NPK fertilizer (5.1). Although organic treatments showed comparatively higher values, the differences were not statistically significant.

Leaf length was significantly influenced by fertilizer treatments ($p < 0.05$). The highest leaf length was observed under OF2 (approximately 8.0 cm), followed by OF1 (7.6 cm) and Control (7.5 cm), while the lowest value was recorded under NPK fertilizer (6.7 cm). OF1 and OF2 were statistically similar, but both performed better than NPK fertilizer. This indicates that organic amendments improved leaf expansion compared to inorganic fertilizer.

Leaf width varied among treatments, with OF2 recording the highest value (6.10 cm), followed by Control (5.40 cm), OF1 (5.13 cm), and NPK fertilizer (4.73 cm). Although statistical significance was not indicated, the trend shows better leaf development under organic fertilizer, particularly OF2.

The number of pods per plant was strongly influenced by fertilizer treatments. The highest pod number was recorded under OF2 (10.53 pods $plant^{-1}$), followed by OF1 (8.50), Control (7.73), and NPK fertilizer (5.70). These results indicate that organic fertilizers, particularly OF2, substantially improved reproductive development compared to inorganic fertilizer.

Pod length was not significantly affected by fertilizer treatments (ANOVA, $p > 0.05$). The highest value was observed under OF1 (8.67 cm), followed by Control (8.50 cm), OF2 (8.47 cm), and NPK fertilizer (7.63 cm). Although slight numerical differences were observed, they were not statistically significant.

Pod width was not significantly affected by fertilizer treatments ($p > 0.05$). Numerically, the highest pod width was recorded in the Control and OF1 treatments (1.20 cm), followed by OF2 (1.17 cm), while the lowest value was observed under NPK fertilizer (1.10 cm). Although slight numerical variation occurred among treatments, these differences were not statistically significant, indicating that pod width remained relatively stable across the fertilizer treatments.

In contrast, the number of grains per pod was significantly influenced by fertilizer treatments ($p < 0.05$). OF1 recorded the highest value (11.00 grains pod^{-1}) and was grouped as "a", while NPK fertilizer produced the lowest value (9.23 grains pod^{-1}) and was grouped as "b". The Control (10.07 grains pod^{-1}) and OF2 (10.30 grains pod^{-1}) were both grouped as "ab", indicating that they did not differ significantly from either OF1 or NPK. These results show that the significant treatment effect was primarily associated with the difference between OF1 and NPK, with OF1 promoting a higher number of grains per pod (Table 2).

Table 2. Number of grains per pod

Treatments	Number of grains per pod
Control	10.07 ab
NPK Fertilizer (100:100:60)	9.23 b
Xir biomass 10% humic acid	11 a
Xir biomass 20 humic acid	10.3 ab
CV (%)	-
ANOVA	*

Hundred-seed weight was not significantly influenced by fertilizer treatments ($p > 0.05$). The highest values were recorded under NPK fertilizer and OF2 (5.33 g), followed by Control (5.00 g), while OF1 had the lowest value (4.67 g). Despite small numerical differences, seed weight remained statistically similar across treatments.
Grain yield was significantly affected by fertilizer treatments ($p < 0.05$). The highest yield was obtained under OF1 (2202.38 kg ha^{-1}), closely followed by OF2 (2107.14 kg ha^{-1}), both statistically superior to NPK fertilizer. The lowest yield was recorded under NPK fertilizer (1726.19 kg ha^{-1}), while the Control (1924.29 kg ha^{-1}) remained intermediate. This indicates that organic fertilizer treatments improved grain yield compared to inorganic fertilizer (Table 3).

Table 3. Grain yield (kg/ha)

Treatments	Grain yield (kg/ha)
Control	1924.29 ab
NPK Fertilizer (100:100:60)	1726.19 b
Xir biomass 10% humic acid	2202.38 a
Xir biomass 20 humic acid	2107.14 a
CV (%)	-
ANOVA	*

Biological yield was significantly influenced by fertilizer treatments ($p < 0.05$). The highest biological yield was recorded under OF2 (7851.63 kg ha^{-1}), followed by OF1 (6923.43 kg ha^{-1}), while Control (5753.99 kg ha^{-1}) and NPK fertilizer (5438.27 kg ha^{-1}) showed lower values. This indicates that organic amendments significantly enhanced total biomass production (Table 4).

Table 4. Biological yield (kg/ha)

Treatments	Biological yield (kg/ha)
Control	5753.99 b
NPK Fertilizer (100:100:60)	5438.27 b
Xir biomass 10% humic acid	6923.43 ab
Xir biomass 20 humic acid	7851.63 a
CV (%)	-
ANOVA	*

Harvest index varied numerically among fertilizer treatments. The highest harvest index was recorded in the Control treatment (12.80%), followed by OF1 (14.19%) and NPK fertilizer (9.33%), whereas the lowest value was observed under OF2 (11.28%). Although differences were observed among treatment means, the statistical significance of the recalculated harvest-index values should be confirmed using plot-level data subjected to ANOVA under the randomized complete block design.

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DISCUSSION

The results of this study indicate that Organic amendments such as farmyard manure (FYM), poultry manure, and compost improved soil organic carbon, moisture retention, and microbial activity, supporting nutrient cycling, soil structure, and resilience to drought (Lehmann & Joseph, 2015; Sunil Kumar & Yadav, 2018; Rizwan et al., 2014). Biochar, while less effective than manure in immediate yield, contributes to long-term soil fertility by enhancing cation exchange capacity, reducing nutrient leaching, and improving water-holding capacity (Zheng et al., 2023; Prapagdee & Tawinteung, 2017; Chan & Xu, 2012).

The positive effects of organic fertilizers observed during the 2025 growing season indicate their potential to improve mung bean growth and yield under the agro-ecological conditions of Kabul. However, because the experiment was conducted during a single growing season, further multi-season studies are recommended to confirm the consistency of these responses under varying environmental conditions such as rainfall and temperature (Choudhary et al., 2015; Khaleeq et al., 2023). Overall, integrating organic fertilizers with biochar and judicious inorganic inputs can optimize nutrient use efficiency, improve crop performance, and maintain long-term soil health in low-input farming systems like those common in Afghanistan (Yadav et al., 2017; Baghlani et al., 2023).

In terms of plant height, plants grown with OF2 exhibited the greatest stature (35.1 cm), significantly exceeding the heights recorded under OF1, NPK fertilizer, and control treatments. This enhanced vegetative growth under organic amendments aligns with findings in multiple studies reporting that organic sources such as farmyard manure (FYM), poultry manure, and compost improve plant height in legumes by supplying a more complete spectrum of macro- and micronutrients, increasing soil organic matter, and enhancing soil physical conditions (Amanullah et al., 2007; Baghlani et al., 2023; Yadav et al., 2017; Diatta et al., 2023; Rizwan et al., 2014). These benefits arise because organic fertilizers release nutrients gradually over time, supporting sustained vegetative growth and enabling plants to maintain nutrient uptake during critical early growth stages (Lehmann & Joseph, 2015). Improved soil structure and aeration under organic amendments also facilitate root expansion and water uptake, further promoting stem elongation and overall growth (Sunil Kumar & Yadav, 2018). In contrast, inorganic NPK fertilizers, though immediately available, may be lost to leaching or immobilized rapidly in the soil, reducing their effectiveness over the full growth period compared to organic nutrient pools (Shil & Bandopadhyay, 2007).

The number of tillers per plant did not show statistically significant differences among treatments, although OF2 consistently showed a numerical advantage. This result reflects findings in other pulse crop studies, where tillering often responds more strongly to genetic potential, plant density, and environmental factors than to fertilizer type alone (Sharif et al., 2020; Mondal et al., 2010). Nevertheless, organic amendments can support higher tiller counts by improving soil moisture retention and nutrient availability, increasing the plant’s capacity to produce secondary shoots (Amanullah et al., 2007; Diatta et al., 2023; Yadav et al., 2017; Rizwan et al., 2014; Sunil Kumar & Yadav, 2018). Improved soil microbial activity under organic amendments may also stimulate the production of plant growth regulators that encourage lateral bud outgrowth, indirectly supporting tiller development.

Similarly, the number of branches per plant did not differ significantly among treatments; however, the highest numerical value was observed with OF2. The limited impact of fertilizer type on branching is consistent with studies indicating that branching patterns in legumes are influenced by hormonal balance and environmental conditions, as well as nutrient availability (Sharif et al., 2020; Rizwan et al., 2014). Although not statistically significant, the trend of increased branching under organic treatments suggests that organic matter amendments may contribute to a more favorable rhizosphere environment, enhancing root growth and soil nutrient cycling, which can support greater vegetative complexity (Amanullah et al., 2007; Yadav et al., 2017; Diatta et al., 2023; Sunil Kumar & Yadav, 2018).

The number of leaves per plant was highest under OF2, though differences were not statistically significant at $P<0.05$. This trend is supported by extensive research indicating that organic fertilizers increase leaf production and expand canopy development due to improved nutrient supply and better soil water status (Baghlani et al., 2023; Yadav et al., 2017; Diatta et al., 2023; Rizwan et al., 2014; Muhammad et al., 2016). Larger and more numerous leaves enhance total photosynthetic capacity, which is a key driver of biomass accumulation and yield formation (Sunil Kumar & Yadav, 2018). In environments where water is a limiting factor, as in much of Afghanistan, improved soil moisture retention under organic amendments supports more robust leaf development compared to mineral fertilizers that do not improve soil structure (Lehmann & Joseph, 2015).

Leaf morphology traits, including leaf length and width, showed significant responses to fertilizer treatments, with OF2 generating the longest and widest leaves. Several studies corroborate this observation, noting that organic sources contribute to larger leaf size by facilitating improved nutrient availability and uptake throughout the crop cycle (Yadav et al., 2017; Muhammad et al., 2016; Baghlani et al., 2023; Diatta et al., 2023; Rizwan et al., 2014). Larger leaf area directly enhances light interception and photosynthetic efficiency, which are essential for carbohydrate synthesis, biomass accumulation, and reproductive success. Enhanced leaf expansion under organic amendments is often associated with higher soil organic matter, improved water retention, and greater microbial diversity that supports nutrient mineralization (Lehmann & Joseph, 2015; Sunil Kumar & Yadav, 2018).

The number of pods per plant, a crucial determinant of grain yield, was markedly influenced by fertilizer application. OF2 produced the highest pod count, followed by OF1 and control, while NPK treatment had the lowest pod number. This result aligns with multiple reports demonstrating that organic amendments improve reproductive development by ensuring nutrient availability during flowering and pod set stages (Muhammad et al., 2016b; Rajput & Memon, 2023; Asghar Malik et al., 2003; Yadav et al., 2017; Degefa et al., 2021). Phosphorus, in particular, plays a vital role in energy transfer and flower initiation, and its gradual availability from organic sources can lead to a greater number of reproductive structures (Sadeghipour et al., 2010). Improved soil health under organic amendments promotes a more stable nutrient supply during critical reproductive windows, which can enhance pod number and reduce abortion.

Pod dimensions showed only limited numerical variation among fertilizer treatments. Pod length was not significantly affected by treatment, although OF1 recorded the highest value (8.67 cm), followed by the Control (8.50 cm), OF2 (8.47 cm), and NPK fertilizer (7.63 cm). Similarly, pod width did not differ significantly among treatments, with the highest values observed in the Control and OF1 treatments (1.20 cm), followed by OF2 (1.17 cm) and NPK fertilizer (1.10 cm). These results indicate that fertilizer type had little influence on pod size under the conditions of this study. Previous studies have reported that organic amendments and balanced nutrient supply can improve pod development in legumes by enhancing nutrient availability and assimilate translocation to reproductive tissues (Sunil Kumar & Yadav, 2018; Yadav et al., 2017; Rizwan et al., 2014; Muhammad et al., 2016; Asghar Malik et al., 2003). However, the absence of significant differences in the present study suggests that pod dimensions may be relatively stable traits and could be influenced more strongly by genetic characteristics and environmental conditions than by the fertilizer treatments evaluated.

Grain yield is the most integrative measure of crop performance and reflects the cumulative effects of vegetative growth, reproductive success, and assimilate partitioning. In this study, OF1 produced the highest grain yield (2202.38 kg ha^{-1}), followed closely by OF2 (2107.14 kg ha^{-1}), both significantly exceeding the yield of NPK treatment (1726.19 kg ha^{-1}) and the control (1924.29 kg ha^{-1}). These findings are corroborated by studies conducted in both South Asia and Africa, which demonstrate that organic nutrient sources often enhance grain yield by improving soil fertility, nutrient retention, and crop nutrient uptake efficiency (Khaleeq et al., 2023; Asghar Malik et al., 2003; Yadav et al., 2017; Rizwan et al., 2014; Diatta et al., 2023). The higher yields under organic fertilizers may be linked to improved soil organic matter, which increases water retention and nutrient supply during key growth stages, alleviating stress and supporting sustained plant development (Lehmann & Joseph, 2015; Sunil Kumar & Yadav, 2018).

The number of grains per pod and 100-seed weight are important quantitative yield components that influence total seed yield. Although these traits were not statistically significant across treatments in this study, organic amendments showed numerical advantages, consistent with research that links improved seed filling and weight to sustained nutrient supply during later growth stages (Rizwan et al., 2014; Yadav et al., 2017; Muhammad et al., 2016; Amanullah et al., 2007; Sunil Kumar & Yadav, 2018). Seed weight, in particular, reflects successful remobilization of carbohydrates and nutrients during the grain-filling period, which is supported by larger leaf area and greater nutrient availability under organic management.

Biological yield, representing total above-ground biomass, was significantly enhanced under OF2 (7851.63 kg ha^{-1}), indicating that organic amendments not only improved grain production but also increased vegetative biomass. This trend aligns with research by Mohammad Tahir et al. (2014), Mondal et al. (2010), Baghlani et al. (2023), Diatta et al. (2023), and Rizwan et al. (2014), who reported that organic fertilizers support greater biomass accumulation due to sustained nutrient supply, increased microbial activity, and enhanced soil physical conditions. Increased biomass contributes to higher photosynthate production, which in turn supports reproductive development and grain filling.

The harvest index (HI), which represents the efficiency of dry-matter partitioning toward grain production, varied numerically among the fertilizer treatments. The highest HI was recorded in the Control treatment (12.80%), followed by OF1 (14.19%) and NPK fertilizer (9.33%), while OF2 produced the lowest value (11.28%). The comparatively lower HI under OF2, despite its higher biological yield, indicates that this treatment favored greater vegetative biomass accumulation without a proportional increase in grain production. In contrast, the relatively similar HI values under the Control, OF1, and NPK treatments suggest a more comparable distribution of assimilates between vegetative and reproductive components. Previous studies have reported that nutrient availability, particularly phosphorus and organic amendments, can influence assimilate translocation, reproductive development, and dry-matter partitioning in legumes (Ahmad et al., 1992; Baghlani et al., 2023; Muhammad et al., 2016; Mohammad Tahir et al., 2014; Yadav et al., 2017). These findings suggest that increased total biomass does not necessarily result in a higher harvest index, as the response depends on the proportion of accumulated dry matter ultimately allocated to grain.

CONCLUSION

In conclusion, fertilizer type significantly influenced several growth and yield traits of mung bean (*Vigna radiata* L.) variety 08 Zudrus. XiR Biomass containing 20% humic acid produced the tallest plants (35.10 cm), the highest number of pods per plant (10.53), and the greatest biological yield (7851.63 kg ha^{-1}), indicating a strong effect on vegetative growth and biomass production. XiR Biomass containing 10% humic acid produced the highest grain yield (2202.38 kg ha^{-1}) and the highest number of grains per pod (11.00). In contrast, pod length, pod width, 100-seed weight, and several vegetative traits were not significantly affected. Overall, both XiR Biomass treatments performed better than NPK fertilizer for several important traits, with the 20% humic acid formulation favoring vegetative growth and biomass production and the 10% formulation favoring grain yield.

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