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ORIGINAL RESEARCH

Impact of Phosphorous and Zinc Levels on the Productivity of Green Gram (*Vigna radiate* L.)

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ABSTRACT

Mung bean is one of the important Kharif pulses in Pakistan and is grown mainly for its edible seeds; therefore, fertilizers management is an important factor for improving mungbean growth and yield. A field experiment was conducted during the summer of 2013 at Palato Farm of the University of Agriculture Peshawar, Amir Muhammad Khan Campus Mardan, to determine the effect of phosphorus (P) and Zinc (Zn) on the yield and yield component of mungbean. The experiment consisted of four levels of P (0, 25, 50, and 75 kg ha^{-1}) and four levels of Zn (0, 5, 10, and 15 kg ha^{-1}). Data associated with the number of leaves and plant height illustrated that the higher number of leaves $plant^{-1}$ (8.8) by an average was observed when P was applied at the rate of 75 kg ha^{-1} followed by 0 kg phosphorous (P) ha^{-1} (8.7) and Zn (Zn) application at the rate of 10 kg ha^{-1}produced a maximum number of leaves $plant^{-1}$ (9) followed by 15 kg ha^{-1}(8.8) where 0 kg ZN ha^{-1} resulted in (7.7). Similarly, Zn significantly affected plant height, while P and interaction between P and Zn levels were non-significant. The higher plant height (95.1 cm) was observed when P was applied at the rate of 75 kg ha^{-1}, followed by 50 kg P ha^{-1} (93.6 cm). Higher plant height (95.8cm) was recorded when ZN was applied at the 5 kg ha^{-1} followed by 10 kg ha^{-1}(95.1cm). Higher numbers of nodules (13.1) were observed with the application of 50 kg P ha^{-1} followed by 75 kg P ha^{-1} (12.3), while the lowest (10.6) nodules were observed in the control plot. P application at the rate of 25 kg ha^{-1} produced a higher grain yield than 75 and 50 kg ha-1 and Zn application at the rate of 5 kg ha-1 produced a higher grain yield than 10 and 15 kg ha^{-1}. Therefore, a lower rate of P 25 kg ha^{-1} and Zn 5 kg ha^{-1} is recommended for a higher yield of mungbean in the agro-ecological condition of Mardan.

KEYWORDS: Mungbean, Zinc, Phosphorous, Yield and Yield components

I. INTRODUCTION

Mungbean (Vigna radiate L.), also called green gram, is an important summer-growing pulse crop in Pakistan (Hakim et al., 2021; Ali et al., 2019; Ahmad et al., 2003). It contains 24.5% protein and 59.9% carbohydrates. It also contains 75 mg calcium, 8.5 mg iron, and 49 mg β-carotene per 100g of split dal (Hakim et al., 2021; Shakya et al., 2019). The foliage and stem are good sources of fodder for livestock. Its seed is more palatable nutritive, digestible, and non-flatulent than other pulses (Teferie et al., 2020; Tarafder et al., 2020). The unique and common feature of mungbean is the root nodules that contain aerobic bacteria called rhizobia which fix atmospheric nitrogen in the root and thus enhance soil fertility (Singh et al, 2021; Ashraf et al., 2003). It is also a substitute for animal protein and forms a balanced diet when used with cereals (Detzel et al., 2021). In Pakistan, mungbean is cultivated as a minor crop and used as food. The area under mungbean in Pakistan was around 141 thousand hectares, with 93 thousand tons in 2011 (Hakim et al., 2021; GOP, 2012).

Fertilizers management is one of the important factors for improving the growth and yield of mung-bean (Ali et al., 2019; Iqbal et al., 2021; Ullah et al., 2020). Phosphorous is an essential component of ADP, ATP, the cell wall, and DNA and plays a key role in promoting plants storage and structural activities (Aimen et al., 2021). P is an important element that significantly affects plant growth and metabolism (Amanullah et al., 2022; Sadiq et al., 2017; Bashir et al., 2011) and is a component of DNA and RNA, involved in cell division (Brady and Weil, 2004). Nodule establishment and its function are important sinks for P, and nodules usually have the highest P content in the plant (Sulieman et al., 2015). It is supposed that P is effectively translocated into grain at high rates since P is necessary for producing protein, phospholipids and phytin in bean grain (Rahman et al., 2008). Poor nodulation and poor plant vigour are observed in beans grown in P deficient soils (Bindraban et al., 2020). Among other essential factors, an appropriate supply of micronutrients is also required for crops' proper growth and yield. The importance of Zn as a micronutrient in crop production has increased in recent years (Amanullah et al., 2020; Thapa et al., 2021). Hence Zn is considered the most yield-limiting micronutrient (Arunachalam et al., 2013).

The Zn application essentially is being employed in the functional and structural components of several enzymes (Amanullah et al., 2020; Read et al., 2019), such as carbonic anhydrase, alcohol dehydrase, alkaline phosphatase, phospholipase, carboxypeptidase (Read et al., 2019) and RNA polymerase (Romheld and Marschner., 1991). Furthermore, plants that emerged from seeds with lower Zn could be susceptible to biotic and abiotic stresses (Rehman et al., 2018). Zn enriched seeds perform better concerning seed germination, seedling growth, and yield of crops (Haider et al., 2020). In addition, Zn acts as an activator of several enzymes in plants and is directly involved in the biosynthesis of growth substances such as auxin, which produces more plant cells (Umair et al., 2020; Gobarah et al., 2006).

Furthermore, Zn enhanced photosynthesis at the early growth of plants, improved nitrogen fixation, grain protein, and yields of mungbean plants (Umair et al., 2020). In Pakistan, Zn scarcity in the soil is the first most widespread problem. In Khyber Pukhtunkhwa, the extent of Zn deficient soils ranges from 21% to 77%. 42% of agricultural fields of Mansehra and Swat have a Zn deficiency. On average, 37% of fields are deficient in Zn (Ahsin et al., 2020).

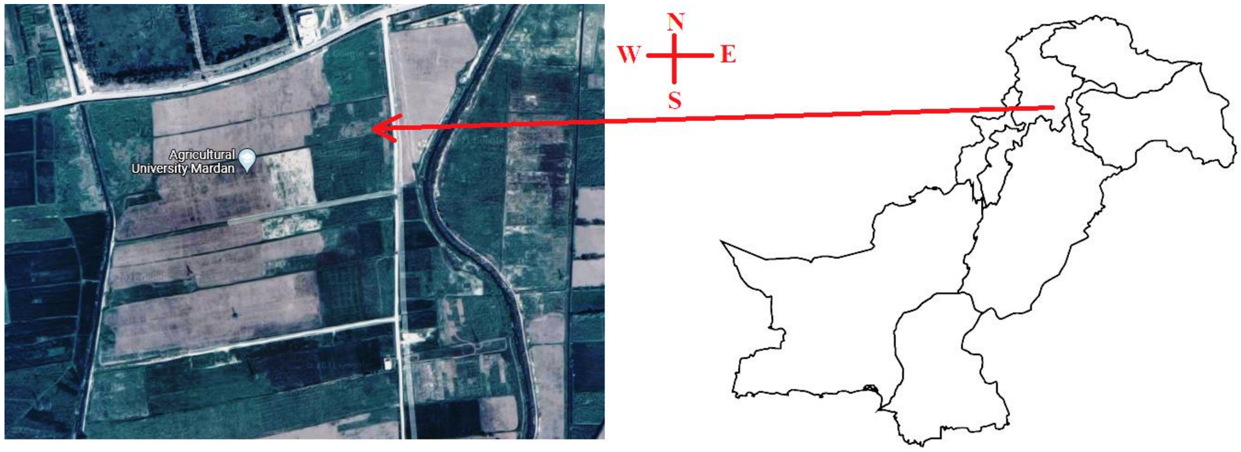

Figure 1. Map representing an experimental location in Mardan city, KPK Province, Pakistan, using Google maps.

Therefore, the present experiment was designed to study the effect of different levels of P and Zn on the yield of mungbean and find out the best combinations of P and Zn for higher yield and yield components of mungbean under the agro-climatic condition of Mardan.

2. MATERIALS AND METHODS

2.1 Experimental design

A field experiment was conducted during the summer of 2013 at Palato Farm of the University of Agriculture Peshawar, Amir Muhammad Khan Campus Mardan (Figure 1), to determine the effect of P and Zn on the yield and yield component of mungbean. The experiment was conducted in a randomized complete block design with three replications, and the plot size was 2 m x 1.8 m. Mungbean variety "Ramzan" was sown in lines having five rows 35cm apart on July 2, 2013. The experiment consisted of four levels of P (0, 25, 50 and 75 kg ha^{-1}) and four levels of Zn (0, 5, 10, and 15 kg ha^{-1}). SSP and $ZnSO_4$ will be used as the source of P and Zn, respectively and applied as a whole during seedbed preparation. All other agronomic practices, such as weeding, irrigation, plant protection measures, etc., were normal and uniform for all the experimental units.

2.2 Data collection and measurement

The number of plants m^{-2} were recorded from three central rows by counting the number of plants within the metering rod of each row and was converted to m^{-2}. Data on the number of branches plant^{-1} was recorded by selecting five plants randomly from each treatment, and the number of branches were counted from base to top and were averaged. The number of leaves plant^{-1} was recorded by selecting five plants randomly from each treatment, and the number of leaves was counted from base to top and averaged. Data on plant height was recorded by randomly selecting five plants from each treatment and measuring its height from base to tip and then averaged to record plant height and averaged them. The number of pod plant^{-1} was recorded by selecting five plants randomly from each plot and then were picked from it, and the number of pods was counted, and then the mean was calculated. Data on the number of grain pod^{-1} was recorded by counting the number of grains from five randomly selected pods in each plot and then averaged. Numbers of nodules plant-1 were recorded by selecting three plants randomly from each treatment, and the number of nodules were counted on roots and averaged. Data on Biological yield (kg ha^{-1}) was recorded by harvesting three central rows in each plot and kept in the field for sun drying. It was weighed with the help of scale and converted into kg ha^{-1} by this formula.

(Weight of bundles/ No. of rows, *Row length * row to row distance) x 10000

Data on grain yield was recorded by harvesting one square meter area from each plot and then were threshed, cleaned, dried, and weighed. The dried grains were weighed with the help of electronic balance and then converted to kg ha^{-1}. Data on thousand grains weight (g) was recorded by counting 1000 grains from each plot and then were weighed with the help of a sensitive electrical balance. The harvest index was calculated using the formula.

Harvest Index (%) = (Grains yield / biological yield) x100

2.3 Statistical analysis

The data were statistically analyzed using analysis of variance techniques appropriate for randomized complete block design. Means were compared using LSD test at 0.05 level of probability when the F-values were found significant (Jan *et al*., 2009).

3. RESULTS

3.1 Phenology and Physiology

Data recorded on the number of branches of plant^{-1} are presented in figure 2-A. In comparison, P and Interaction between P and Zn levels was found non-significant. The mean value of the data indicated that a higher number of branches plant^{-1} (1.88) was recorded when P was applied at the rate of 75 kg ha^{-1} followed by 50 kg P ha^{-1} (1.83) where 25 kg P ha^{-1} results number of branches plant^{-1} (1.17). The higher number of branches plant^{-1} (1.93) was recorded when Zn was applied at the rate of 10 kg ha^{-1} followed by 15 kg ha^{-1}(1.92), .where 0 kg Zn ha^{-1} resulted in the lower number of branches plant^{-1} (1.58).

Data recorded on the number of plants m^{-2}, are presented in figure 2-B. Statistical analysis of the data showed that Zn had a significant influence on the number of plants m^{-2} while P and interaction between P and Zn levels were found non-significant. The mean value of the data indicated that a higher number of plants m^{-2} (22.9) was recorded when P was applied at the rate of 75 kg ha^{-1}, followed by a control plot (21.6), whereas 25 kg P ha^{-1} had the least number of plant m^{-2} (20.3). The higher number of plants m^{-2} (24) was recorded when Zn was applied at the rate of 15 kg ha^{-1} followed by 10 kg ha^{-1}(23), where the least number of plant m^{-2} (17) were noted in the plot where no Zn was applied.

Data recorded on the number of leaves plant^{-1} are shown in figure 2-C. Statistical analysis of the data shows that P and Zn significantly influence the number of leaves plant^{-1}. While Interaction between P and Zn levels was found non-significant. The mean value of the data indicated that a higher number of leaves plant^{-1} (8.8) was observed when P was applied at the rate of 75 kg ha^{-1} followed by 0 kg phosphorous ha^{-1} (8.7), where 50 kg P ha^{-1} resulted in the lower number of leaves plant^{-1} (8). The higher number of leaves plant^{-1} (9) was recorded when Zn was applied at the rate of 10 kg ha^{-1} followed by 15 kg ha^{-1}(8.8), where 0 kg Zn ha^{-1} resulted in (7.7) lower number of leaves plant^{-1}.

Data associated with plant height are presented in figure 2-D. Statistical analysis of the data shows that Zn significantly affects plant height while P and Interaction between P and Zn levels were found non-significant. Mean data shows that higher plant height (95.1) was observed when P was applied at the rate of 75 kg ha^{-1} followed by 50 kg P ha^{-1} (93.6), where 0 kg P ha^{-1} results from low plant height (88.6). Higher plant height (95.8) was recorded when Zn was applied at the 5 kg ha^{-1} followed by 10 kg ha^{-1}(95.1). Where 0 kg Zn ha^{-1} resulted in lower plant height (81.9).

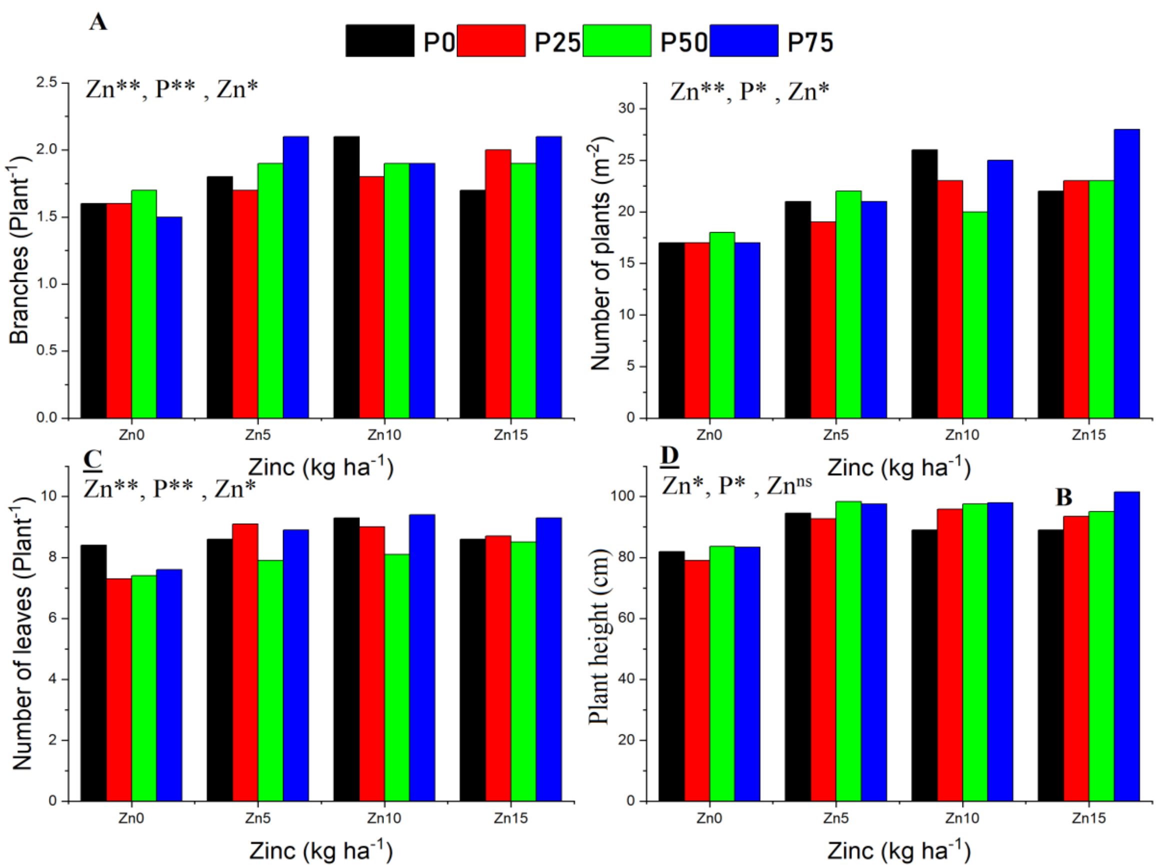

Figure 2. Effect of P and Zn on the number of plants m^{-2}, number of branches plant^{-1} , number of leaves plant^{-1} and plant height (cm) of mungbean.

3.2 Grain yield and yield traits (kg ha^{-1})

Results showed that P and Zn levels significantly affected the number of pods (figure 3A). While Interaction between P and Zn levels was found non-significant (Figure 3). The mean value of the data indicated that higher numbers of pods (10.3) were observed when P was applied at the rate of 25 kg ha^{-1} followed by 75 kg P ha^{-1} (10), where the control plot resulted in the lower number of pods (9.2). For Zn, higher numbers of pods (10.2) were observed when Zn was applied at the 5 kg ha^{-1} followed by 10 kg Zn ha^{-1}(10.1). Control plots resulted in lower numbers of pods (9). Similarly the grains pod^{-1} were also affected by Zn and P application (Figure 3B). In comparison, P and interaction between P and Zn levels were found non-significant. Mean data shows that a maximum number of grains pod^{-1} (10.1) was observed when P was applied at the rate of 50 kg ha^{-1} followed by 25 kg P ha^{-1} (10). Whereas P application at the rate of 50 kg ha^{-1} resulted in a lower number of grains (9.6). The higher number of grain pod^{-1} (10.3) was recorded when Zn was applied at the rate of 5 kg ha^{-1} followed by 10 kg ha^{-1}(10), whereas the control plot resulted in the lower number of grains (8.7).

Maximum numbers of nodules (13.1) were observed with the application of 50 kg P ha^{-1} followed by 75 kg P ha^{-1} (12.3), while the lowest (10.6) nodules were observed in the control plot (Figure 3C). Similarly, higher numbers of nodules (12.7) were observed with the application of 15 kg Zn ha^{-1} and followed by the control plot (11.7), while the lowest (11.1) nodules were observed on 10 kg Zn ha^{-1}. Results on grain yield showed that that a higher grain yield (826.7 kg ha^{-1}) was observed when P was applied at the rate of 25 kg ha^{-1}, followed by 50 kg P ha^{-1} (792.5 kg ha^{-1}), where a lower grain yield (737.4 kg ha^{-1}) were obtained from the control plot. Higher grain yield (835.0 kg ha^{-1}) was recorded when Zn was applied at the rate of 5 kg ha^{-1} followed by 15 kg ha^{-1} (800 kg ha^{-1}). Whereas lower grain yield (719.9 kg ha^{-1}) was recorded at plot had 10 kg Zn ha^{-1}.

Maximum (4493.4 kg ha^{-1}) biological yield was observed with the application of 25 kg P $ha^{-1,}$ while the lowest (3543.1 kg ha^{-1}) biological yield was observed for 75 kg P ha^{-1} (Table 1). Similarly, Zn has a maximum biological yield (4511.1 kg ha^{-1}) with the application of 15 kg ha^{-1}, while the lowest (3630.3 kg ha^{-1}) was recorded in the control plot. Higher (39.4) thousand-grains weight was observed with the application of 25 kg P ha^{-1}.followed by (38.8g) at the rate of 75 kg p ha^{-1} (Table 2). While the lowest (36.8g) thousand grains weight were observed for the control plot. Similarly, Zn has a significant influence on thousand grains weight, having a higher thousand grains weight (42.3g) for application of 15 kg Zn ha^{-1}, while the lowest (34.4g) thousand grains weight was recorded in the control plot. P and Zn had significant effects, while their interaction was non-significant. The higher harvest index (21.73%) was observed when P was applied at the rate of 75 kg ha^{-1} followed by 0 kg ha^{-1} (20.54%), where 25 kg ha^{-1} resulted in a lower harvest index (19.30%) (Table 3).. For Zn higher harvest index (23.0%) was observed when Zn was applied at the rate of 5 kg ha-1, followed by a control plot (21.3%).

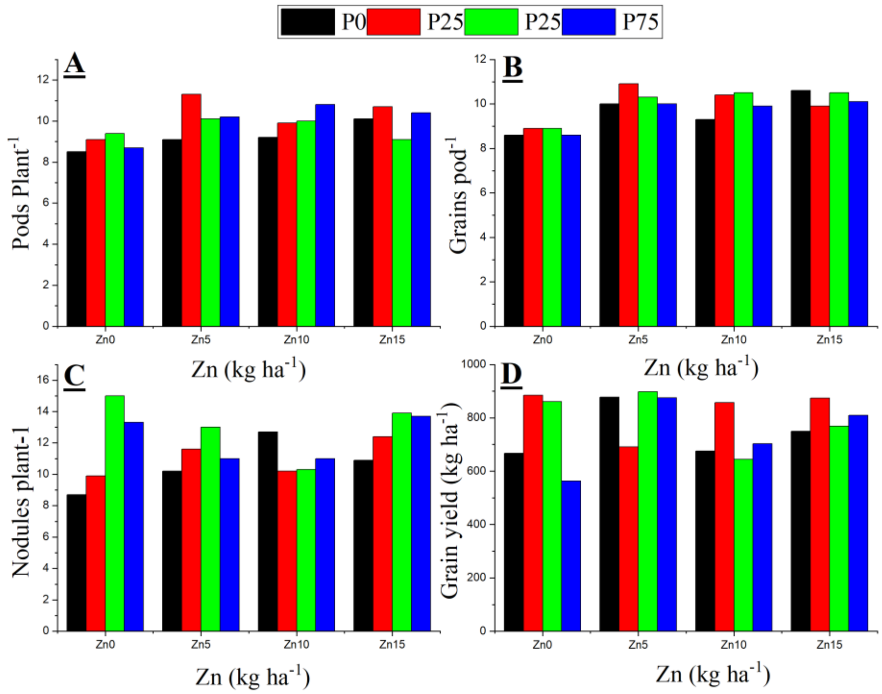

Figure 3. Effects of P and Zn application on pods plant^{-1} , grains pod^{-1}, nodules plant^{-1} and grain yield (kg ha^{-1}) of mungbean.

Table 1. Effects of P and Zn on biological yield of mung bean.

Zn (kg ha^{-1})	P(kg ha^{-1})				
	Control	25	50	75	Mean
Control	3233.1	4203.9	4301.1	2782.9	3630.3b
5	3515.4	4456.7	4001.7	3147.7	3780.4b
10	3885.2	4680.1	3659.4	3476.7	3925.3ab
15	4328.1	4632.9	4318.2	4765.0	4511.1a
Mean	3740.5b	4493.4a	4070.1ab	3543.1b	

Table 2. Effects of P and Zn on thousand-grain weight (gram) of mungbean.

Zn (kg ha^{-1})	P(kg ha^{-1})				
	Control	25	50	75	Mean
Control	29.7	38.0	34.2	35.7	34.4d
5	37.3	38.0	37.3	37.1	37.4c
10	38.7	39.3	40.0	39.0	39.3b
15	41.3	42.3	42.2	43.4	42.3a
Mean	36.8b	39.4a	38.4a	38.8a	

Table 3. Effects of P and Zn on harvest index of mung bean.

Zn (kg ha^{-1})	P(kg ha^{-1}) control	25	50	75	Mean
Control	21.2	23.3	20.2	20.5	21.3ab
5	25.1	16.0	22.7	28.5	23.0a
10	17.9	18.4	18.1	20.8	18.8b
15	18.0	19.6	18.5	17.2	18.3b
Mean	20.54a	19.30a	19.89a	21.73a	

Mean followed by different letters are found significant at 5% level of probabilities.

Furthermore, the application of 15 kg Zn ha^{-1} resulted in a lower harvest index (18.3%).

4. DISCUSSION

Micronutrient insufficiency is the primary cause of low crop development and production in arable soils (Imtiaz et al., 2011). Due to intensive agricultural practices, unwise use of mineral nutrition, breeding of high yielding and advanced varieties, and removal of huge quantities of nutrients at every crop harvest with lower nutrients returns to soils, the degree and extent of nutrient deficiency in arable soils has recently had serious consequences, resulting in lower micronutrients including zinc (Zn) in soil (Kanwal et al., 2019). Therefore to we conducted a field experiment on different Zn rates in combination with P rates to determine its effect on mungbean growth, yield and yield components. Our results showed that P and Zn significantly effected number of plants m^{-2} , number of branches $plant^{-1}$, number of leaves $plant^{-1}$ and plant height (cm) pods $plant^{-1}$, grains pod^{-1}, nodules $plant^{-1}$ and grain yield (kg ha^{-1}) , biological yield, thousand grains weight, and harvest index. The plots treated with 15 kg ha^{-1} Zn in combination with 50 kg P ha^{-1} Resulted in higher number of plants m^{-2}, more branches $plant^{-1}$, maximum leaves $plant^{-1}$ and maximum plant height (cm), higher number of pods $plant^{-1}$, more grains pod^{-1},extra nodules $plant^{-1}$ and higher grain yield (kg ha^{-1}). The possible explanation for these increments might due to the Zn promotes nodulation and nitrogen fixation in leguminous crops (Masood, et al., 2022; Shahrajabian et al., 2022; Gough et al., 2021). Furthermore Zn is important in the formation of auxin, which increases cell volume and increases plant height (Wang et al., 2016; Oguchi et al., 2004). Cakmak et al. (2000) reported that Zn is essential for active enzymatic activity, root cell elongation, and reducing free radical damage to the cell. Another possible explanation for these results that when Zn and P applied to soil improved soil physical and chemical properties which consequently improved mungbean growth, yield and yield component (Singh, et al., 2013). A previous study documented that compared to control, Zn increased branches numbers in plants and leaf area of mungbean (Haider et al., 2021). Nair studied the genetic diversity of mungbean for iron and zinc and discovered a large potential for improvement through biofortification, finding 20–40 g Zn concentration kg^{-1} for dry mungbean seed, which was virtually identical in our work. Overall the results showed that the addition of Zn and P fertilizer to soil can improve growth, yield and yield component of mungbean.

5. CONCLUSION

Our results showed that the growth, yield and yield components of mungbean were improved in Zn and P fertilizer application. On the basis of our results it is concluded that P application at the rate of 25 kg ha^{-1} produced a higher grain yield as compared to 75 and 50 kg ha^{-1}. Whereas, Zn application at the rate of 5 kg ha^{-1} produced a higher grain yield than 10 and 15 kg ha-1 hence lower rate of 5 kg ha-1 is recommended for higher yield of mungbean in agro-ecological condition Mardan.

Authors Contributions:
A.M and F.M conceived the main idea of research, A.M wrote the manuscript. H.N, A.R and I.K revised the manuscript and provided suggestions. In addition A.M and A.R assessed and analyzed the data, and performed data collection. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest
The authors declare no conflict of interest.

Data Availability statements: The data presented in this study are available on request from the corresponding author.

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