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Integrated Approach of Organic and Inorganic Fertilizer Management on Nutrient Composition and Uptake of Mungbean (*Vigna radiata* L.) in Udic Rhodustalf Soil

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Authors' contributions

This work was carried out in collaboration among all authors. Author ST conducted the experiment, data collection and the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MAR managed the analyses of the study, literature searches, data presentation and helped in manuscript preparation. Authors MAH and MAHC designed the study, managed the literatures and wrote the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Background: Pulses are important food crops that can play a major role in achieving food security, nutrition, and human health, contributing to the sustainability of agriculture and aiding the mitigation and adaptation to climate change. The nutrient uptake is directly or indirectly affected by many factors like total concentration as well as available quantity of different nutrients, root development, aeration, water potential, climatic conditions and other related soil parameters.
Aims: A field experiment was carried out to find out the effects of different manures along with inorganic fertilizers on nutritional status of two mungbean varieties.

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Study Design: Experimental treatments consisted of eight combinations of each manure and inorganic fertilizers with Soil Test Base (STB).

Results: The results showed that integrated effects were found significant on Ca, Zn and Mn contents in seed and P, Mg, Fe, Cu, Zn and Mn contents in stover. The highest N (4.34%), Mg (0.48%), P (0.56%) contents in seed and N (1.52%), Mg (0.78%) and B (30.67 µg g^{-1}) contents in stover was obtained by the application of 3 t ha^{-1} poultry manure + 70% STB. The highest seed protein content was found from the same treatment. On the other hand, the highest Zn, Mn, Cu and S contents in seeds, and Zn, Fe and K contents in stover were obtained from 3 t ha^{-1} vermicompost + 70% STB. The treatment of 3 t ha^{-1} poultry manure + 70% STB produced the highest uptake of N, P, K, Ca, Mg, Zn, Mn, and Cu in seeds and the highest uptake of Mg, Fe and B was found with stover. The nutrient contents of seeds were positively and significantly correlated with each other. In Principal Component Analysis (PCA), the first two principal components accounted for approximately 81.80% of the total variability. BARI Mung-6 appeared as the best variety and poultry manure @ 3 t ha^{-1} along with 70% inorganic fertilizers treatment for the better nutritional quality of Mungbean.

Conclusion: It was observed that different treatments performed differently in respect of nutrients contents and uptake of seed and stover, and protein contents. From the above experimental findings, it is concluded that BARI Mung-6 appeared as the best variety and poultry manure @ 3 t ha^{-1} along with 70% IF should be applied for getting better nutritional mungbean seed with higher protein contents under the agroclimatic condition of BARI.

Keywords: Concentration; integrated effects; mungbean; PCA; Uptake.

1. INTRODUCTION

Priority of agriculture today has been shifted towards nutritional security of growing population and the demand for diversified food items which are new challenges to agriculture. Pulses are important food crops that can play a major role in achieving food security, nutrition, and human health, contributing to the sustainability of agriculture and aiding the mitigation and adaptation to climate change [1]. In terms of nutrition and food security, pulses provide a good source of plant-based protein as well as fibre, vitamins (e.g., B vitamins) and minerals such as iron, potassium, magnesium and zinc [2]. Mungbean (*Vigna radiata* L.), commonly known as green gram has an edge over other pulses because of its high nutritive value, digestibility and non-flatulent behavior [3]. It contains 51% carbohydrate, 24 to 26% protein, 4% mineral, and 3% vitamins [4]. An important feature of the mungbean crop is its ability to establish a symbiotic partnership with specific bacteria, setting up the biological N_2-fixation in root nodules that supplies the plant's needs for N_2 [5,6].

Agriculture remains a soil–based industry, there is no way that required yield increases of the major crops can be attained without ensuring that plants have an adequate and balanced supply of nutrients [7,8]. The appropriate environment must exist for nutrients to be available to a particular crop in the right form and amounts, both absolute and relative, and at the right time for high yields to be realized in the short and long term [9] with minimizing the pollution [10]. The primary nutrients for plant growth e.g., nitrogen, phosphorus, and potassium [11] are most often responsible for limiting crop growth and less intensively used secondary nutrients (sulfur, calcium, and magnesium) are necessary as well [12,13]. A number of micronutrients are required in small amounts for the proper functioning of plant metabolism and proper growth [14,15]. The absolute or relative absence of any of these nutrients can hamper plant growth; on the other hand, too high concentrations can be toxic to both plants and humans [16,17].

The nutritional composition of plants is a translation of the conditions under which they complete their life cycle fully or partially which known as a net summary of all the changes either positive or negative [18]. The nutrient uptake is directly or indirectly affected by a number of factors such as total concentration as well as available quantity of different nutrients, root development, aeration, water potential, climatic conditions and other related soil parameters [19]. Besides all these, the presence of a nutrient in available form for the plant has to play the deciding role. When organic materials are applied along with inorganic fertilizers, the overall fertility status of the soil is buildup the total reserve of nutrients in increasing level and create a stage for enhanced availability [20]. Ayalew and Dejene [21] stated that integrated nutrient management is the best approach to supply adequate and balanced nutrients and increase crop productivity in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. Integrated nutrient management is the supply of the required plant nutrients for sustaining the desired crop productivity with minimum deleterious effect on soil health environment [22]. Inadequate and imbalanced nutrient application by farmers is the most important limiting factor in pulse crop production. It is now increasingly being realized that no single nutrient source could fully meet the nutritional requirement of crop. Moreover, injudicious use of chemical fertilizers enhanced the soil and plant health problems. In this context, integration of organic manure and inorganic fertilizers have been found to be promising not only in maintaining higher productivity of crops and for providing stability in crop production, besides improving soil physical conditions [23]. Keeping in view, the present investigation was carried out to study the effects of integrated nutrient management on quality and nutrient contents and uptake of mungbean under field conditions.

2. EXPERIMENTAL DESIGN

The experiment was conducted during the Kharif -2 season (Mid July to mid November) of 2018 at the Soil Science Sub-Station, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur (24°0′13″N latitude and 90°25′0″E longitude) which lies at an elevation of 8.4 m above the sea level. The crop field was medium high land with clay loam soil and it belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agroecological zone Madhupur Tract (AEZ-28). Udic Rhodustalf is a hyperthermic, isomesic, or warmer iso soil temperature regime and a moisture control section that in normal years is dry in some or all parts for less than 120 cumulative days per year when the temperature at a depth of 50 cm below the soil surface is higher than 8°C.

Before land preparation, initial soil samples (0 - 15 cm depth) were collected from different spots of the field and was stored for analyses of physical and chemical properties following the standard methods [24]. Initial characteristics of the experimental field soil and nutrient status of different organic manure sources can be seen from Tarafder et al. [25]. The seeds of BARI mung-6 for the experiment were collected from BARI, Joydebpur, Gazipur, and BINA Mung-8 was collected from Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. BARI mung-6 was released and developed by BARI in 2003. Plant height of the cultivar ranges from 40 to 45 cm. It is resistant to *Cercospora* leaf spot and tolerant to yellow mosaic virus. Its life cycle is about 55 to 58 days after emergence. One of the main characteristics of this cultivar is synchronization of pod ripening. Average yield of this cultivar is about 1800 kg ha^{-1}. BINA Mung-8 is a summer mungbean variety released in 2010. Maturity period ranges from 64-67 days. Maximum grain yield is about 2.0 t ha^{-1} (av. 1.8 t ha^{-1}). Seed is medium size with green shiny color. Seed contains higher protein (23%). Plants are short and tolerant to yellow mosaic virus (YMV) disease. The experiment was laid out following randomized complete block design (RCBD) with three replicates. The experiment consists of 8 treatments viz. T_1 = control, T_2 = 100% soil test base (STB) inorganic fertilizer (IF) dose, T_3 = 2.5 t ha^{-1} cowdung (CD) + 85% STB, T_4 = 5 t ha^{-1} CD + 70% STB, T_5 = 1.5 t ha^{-1} poultry manure (PM) + 85% STB, T_6 = 3 t ha^{-1} PM + 70% STB, T_7 = 1.5 t ha^{-1} vermicompost (VC) + 85% STB, T_8 = 3 t ha^{-1} VC + 70% STB. Each plot was 12 m^2 (4 m x 3 m) in size further divided into two portions for the two varieties. The distance maintained between two plots was 0.6 m and between blocks was 1.5 m.

All fertilizers were applied following broadcasting method and incorporated during land preparation. The basal dose of N, P, K, S, Zn and B @ 40, 90, 30, 40, 5 and 6 kg ha^{-1} [26] from urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively and CD (2.5 t ha^{-1} and 5 t ha^{-1}), PM (1.5 t ha^{-1} and 3 t ha^{-1}) and VC (1.5 t ha^{-1} and 3 t ha^{-1}) was applied. In case of full dose of manures 70% of IF and for half dose 85% of inorganic fertilizer were applied. Mungbean seeds were sown on the 12 August, 2018 in lines following the assigned line to line distance of 30 cm and plant to plant distance of 10 cm. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm at the rate of 30 kg ha^{-1}. The seeds were treated by Provex 200 @ 3 g kg^{-1} seed before sowing to control diseases.

Different intercultural operations were done as and when necessary. The crops were harvested when 90% of the pods were matured at two phases. The first phase was on 9th October and the second on 23rd October, 2018. The harvested crops were dried in the sunlight. The seed yield was measured at 9% moisture level. The seed and stover yield (t ha^{-1}) per plot were recorded while cleaning up and sun-drying. After drying and grinding, chemical analysis of seed and stover was done following the standard procedure described by American Public Health Association [27]. The dried powdered samples were first digested with nitric acid and perchloric acid and then the aliquots were used for the determination of N, P, K, Ca, Mg, S, Fe, Cu, Zn, B and Mn contents. Total N content of the seed was determined by the semi-micro Kjeldahl method. Protein present in seeds was calculated by the following formula [28]:

$$\text{Protein (\%)} = \%\ N \times 6.25$$

Calcium and Mg contents in plant extract were determined by EDTA titrimetric method. Phosphorous, S and B were determined by spectrophotometer (Model: TG-60 U) while potassium was determined by flame photometer (Model-Jenway PET 7). Iron, Cu, Zn, and Mn were determined directly by atomic absorption spectrophotometer (Shimadzo, AA7000, Japan). Nutrient uptake was calculated from nutrient contents and seed and stover yield using following formulae:

Nutrient uptake of seeds =

$$\frac{\text{Nutrient content (\%) in seed}}{100} \times \text{Seed yield (kg ha}^{-1}\text{)}$$

Nutrient uptake of stover =

$$\frac{\text{Nutrient content (\%) in stover}}{100} \times \text{Stover yield (kg ha}^{-1}\text{)}$$

The seed and stover yield of the two varieties (BARI Mung 6 and BINA Mung 8) can be seen from our previous published scientific article [25]. Data were statistically analyzed for analyses of variance (ANOVA) using the MSTATC Statistical Computer Package Program (Michigan State University) in accordance with the principles of RCBD. Duncan's Multiple Range Test (DMRT) was used to compare variations among the treatments [29]. Principal component analysis (PCA) was performed using R statistical software package program.

3. RESULTS AND DISCUSSION

3.1 Effects of Integrated Nutrient Management on Nutrient Contents in Seeds and Stovers of Mungbean

3.1.1 N, P, K, S, Ca and Mg contents

The integrated effects of variety and different levels of manures along with IF on N contents of seed and stovers are not significant (Table 1). The highest N contents in seeds (4.34%) and stover (1.52%) were found from V_1T_6 and the lowest in both from V_2T_1 (Table 1). The concentration of N was higher in the seed than in the stover at harvest, indicating translocation of N from stover to seed. During grain filling, N content of non-grain tissue generally decreases while grain N content increases [30,31]. As PM contained more N than other organic amendments, it showed the higher N concentrations in seed and stover. Similar observations were previously reported by Soremi et al. [32] who showed the highest concentrations of N, P and K in plant tissues were mostly obtained at 7.5 and 10 t ha^{-1} of PM.

Phosphorus content of seeds was not significantly influenced by different treatments but in case of stover the effect was significant (Table 1). The highest P content of seeds was obtained from V_1T_6 (0.58%) and the lowest from V_2T_1 (0.38%). Again, P content ranged from 0.13 to 0.38 in stover. The highest P content of stover was obtained from V_2T_6 (0.38%), followed by V_2T_2 (0.36%). The lowest P content of stovers was found in V_1T_1. Phosphorus content was also higher in seed than in stovers, also indicating translocation of P from stover to seed [33]. This finding was in line with Rupa et al. [34] who observed the highest P content in seed (0.47%) by applying poultry manure @10 t ha^{-1}.

Different levels of manures and inorganic fertilizers had no significant influence on K and S contents of seeds and stover (Table 1). The K contents in both seeds and stovers were found to be highest from V_2T_8 (1.5% and 2.19% respectively) and the lowest from V_1T_1 (1.23% and 1.64% respectively). Potassium content was higher in stovers than in seeds, also indicating translocation of K to vegetative parts [33]. This finding was in line with previous reports [35,36]. Rupa et al. [34] found maximum N, P and K contents in seed were 3.56, 0.47, 1.25% obtained by applying 10 t ha^{-1} PM. The highest S content in seed was found from V_1T_8 (0.29%) and lowest from V_2T_1 (0.17%). Similarly, the highest and lowest S content of stover was obtained from V_2T_8 (0.19%) and V_1T_1 (0.10%), respectively. Overall, S concentration was higher in the seeds than in the stovers. This might be due to improved nutritional environment in the rhizosphere as well as its utilization in the plant system leading to enhanced translocation to reproductive structures viz., pods, seeds and other plant parts.

Calcium content of seeds of mungbean was significantly influenced by integrated nutrient management but not significantly for stovers (Table 1). Maximum Ca content of seeds was obtained from V_2T_6 (0.48%) and the lowest from V_1T_1 (0.18%). Again, the highest Ca content of stover was obtained from V_2T_6 (2.33%). The lowest Ca content was found in V_1T_1 (1.64%). The increasing rate of PM increased the Ca content in mungbean. The combined effects of different levels of manures along with IF on Mg content of seeds was not significant but it was for stovers. The maximum Mg contents were found in V_1T_6 from both seeds and stovers (0.48% and 0.78%, respectively) and similarly for the minimum in V_2T_1 (0.22% and 0.41% respectively). Results showed that the higher Mg concentrations in seed and stover was obtained with the application of PM because of containing more Mg in this organic amendment. The amount of Ca and Mg were higher in stover than in seed. Calcium and magnesium in stems and leaves increased from vegetative to harvest stage but Ca and Mg in reproductive parts declined [33]. The results confirm that the application of manure influenced the Mg content of mungbean. The result was in conformity with previous study [37]. Akanbi et al. [38] conducted field trials with pig droppings (manure) in okra (*Abelmoschus esculentus* moench) cultivation and found increased N, P, K, Ca and Mg in its fruit.

3.1.2 Seed protein content

Protein content was increased significantly by the application of IF and different organic manures like PM and VC compared to the control (Table 1). The maximum protein content was obtained from the combination of V_1T_6 (27.10%) and minimum amount from V_2T_1 (17.38%). Increased N concentration might have increased the protein content. On the contrary, lowest protein content in control might be due to lower seed yield on account of reduced growth and development of mungbean due to poor nutrition of the crop resulted in poor development of seed and consequently, reflected in lower protein content. Yadav et al. [39] recorded the highest protein content of 15.61% under 50% N (urea) + 50% N (PM) treatment for okra.

3.1.3 Zn, Fe, Mn, B and Cu contents

The combined effects of different levels of manure and IF on Zn content of seeds and stovers were significant (Table 2). The highest Zn content of seeds was found in V_1T_8 (37.03 µg g^{-1}), followed by V_1T_6 (36.27 µg g^{-1}) and the lowest from V_1T_1 (32.83 µg g^{-1}). In case of stover, the highest amount of Zn was found in V_1T_8 (32.50 µg g^{-1}), followed by V_2T_8 (30.43 µg g^{-1}). Poultry manure contained relatively more Zn than other manures which could result in increased availability and subsequently content in both seed and stover. This is in close agreement with the findings by Leytem and Bjorneberg [40] and previous reports [37,41,42].

Although interaction of varieties and different levels of manures along with IF on Fe content of seeds was not significant, the Fe content of stover was significantly varied (Table 2). The highest Fe content in seeds was observed in V_2T_8 (124.10 µg g^{-1}) and the lowest in V_1T_1 (108.90 µg g^{-1}). Maximum Fe content in stover was obtained from V_1T_8 (305.10 µg g^{-1}) and the lowest from V_1T_1 (256.30 µg g^{-1}). These results are in accordance with the previous findings in case of these nutrients contents of mungbean and other crops [43,44,45].

The variation was found due to combined effects of varieties and different levels of manures along with inorganic fertilizers on Mn content of seeds and stovers (Table 2). The highest (17.24 µg g^{-1}) Mn content of seeds was found in V_1T_8, followed by V_1T_6 (16.91 µg g^{-1}) and V_1T_4 (16.64 µg g^{-1}) and the lowest (13.43 µg g^{-1}) from the combination of V_2T_1. On the other hand, the highest Mn content of stover was obtained from V_2T_8 (87.10 µg g^{-1}) treatment and the lowest from V_1T_1 (62.33 µg g^{-1}). Similarly, the highest B content of seeds was found from V_1T_6 and V_2T_8 (14.67 µg g^{-1}) and the lowest from V_2T_1 (10.33 µg g^{-1}). The highest and lowest B content of stovers was 30.67 µg g^{-1} (V_1T_6) and 21.67 µg g^{-1} (V_2T_1), respectively (Table 2). Though combined effects of variety and different levels of manures along with IF on Cu content of seeds was not affected significantly, Cu content of stover was affected significantly (Table 2). The highest Cu content in seeds was found in V_1T_8 (14.60 µg g^{-1}) and the lowest from V_2T_1 (11.75 µg g^{-1}). Again, the highest Cu content in stovers was found in V_2T_8 (14.07 µg g^{-1}). These results are in accordance with the previous findings [43,44,45]. Addition of manure rich in organic matter resulted in large concentrations of nutrients in plant tissues [46] due to the release in available form largely through the action of microbes [47].

3.2 Effects of Integrated Nutrient Management on Nutrient Uptake in Seeds and Stovers of Mungbean

3.2.1 N, P, K, S, Ca and Mg uptake

Interaction between different levels of manure and IF had no significant influenced on N uptake of seed and stover (Table 3). The highest N uptake in seed and stover was found in V_1T_6 (91.41 kg ha^{-1} and 52.01 kg ha^{-1}), respectively whereas the lowest from V_1T_2 (33.75 kg ha^{-1}) in case of seed and from V_2T_1 (33.36 kg ha^{-1}) for stover. The immobilization and mineralization of N in the soil could be regulated by the addition of organic matter to improve the N uptake. The findings were in agreement with the previous result [48] for soybean. The increased N uptake could be ascribed to slow and continued supply of the nutrients, coupled with reduced N losses via denitrification or leaching, which might have improved the synchrony between plant N demand and supply from the soil [49,50].

The combined effect of different levels of manures along with IF on P uptake of seeds was insignificant whereas significant result was found for stovers (Table 3). The highest P uptake of seeds and stover was obtained from V_1T_6 (12.24 kg ha^{-1}) and V_2T_6 (13.32 kg ha^{-1}), respectively whereas the lowest from V_2T_1 (4.57 kg ha^{-1}) and V_1T_1 (3.62 kg ha^{-1}), respectively. Increase in the uptake of these nutrients with the integrated application of IF and PM may be due to better availability of these nutrients due to added supply and because of prolific root system developed by the balanced nutrient application resulting in better absorption of nutrients and water. The highest K uptake was found from V_1T_6 (29.87 kg ha^{-1}) and lowest from V_2T_1 (15.52 kg ha^{-1}). Similarly, the highest and lowest K uptake of stover was 79.56 kg ha^{-1} (V_2T_8) and 44.77 kg ha^{-1} (V_1T_1). Similar findings of K content were obtained by previous study [48,51,52]. Organic fertilizer provides significant cation exchange capacity to hold cations such as K^+. The change in cation exchange capacity of organics by acidification might have enhanced K availability [53,54]. Almaz et al. [48] showed that for both maize and soybeans, the highest uptake of N, P and K was observed from the integrated application of 50% NPK +50% PM. Morya et al. [55] found that application of 50% RDF (10:30:20 kg NPK ha^{-1}) + 50% VC (2.5 t ha^{-1}) recorded higher N, P and K uptake followed by 100% RDF. Bidanchandra [56] reported that enriched compost increased N and P uptake in green gram.

Calcium and S uptake of seeds and stover of mungbean was not significantly influenced by the combination of variety and different levels of manure along with IF (Table 3). The highest S uptake was found from V_1T_8 (5.50 kg ha^{-1}) and lowest from V_2T_1 (2.07 kg ha^{-1}). Similarly, the highest and lowest S uptake of stover was obtained from V_2T_8 and V_1T_1, respectively. Integrated uses of manures and IF release macronutrients in the soil. The highest Ca uptake of seeds was obtained from V_1T_6 (8.92 kg ha^{-1}) and the lowest from V_1T_1 (2.31 kg ha^{-1}). Again, the highest Ca uptake of stover was obtained from V_2T_6 (81.78 kg ha^{-1}). The lowest Ca uptake was found in V_1T_1. The effects of manure application were beneficial in enhancing the uptake of Ca by mungbean. An increase in macronutrients would help in the proliferation of soil microflora in general, which, in turn, influence the rate of mineralization, facilitating the increased availability and uptake of essential nutrients.

The combined effects of variety and different levels of manures along with IF on Mg uptake of seeds and stover was significant (Table 3). The highest Mg uptake in seeds (10.17 kg ha^{-1}) and stover (29.31 kg ha^{-1}) was found in V_1T_6. The lowest Mg uptake both of seeds (2.67 kg ha^{-1}) and stover (11.87 kg ha^{-1}) from V_2T_1. Maximum Ca and Mg uptake was recorded by plants treated with enriched VC. The higher content of these cations presents in plants treated with enriched VC may be due to increased uptake through enhanced availability from the soil [57].

3.2.2 Zn, Fe, Mn, B and Cu uptake

The combined effects of variety and different levels of manures along with IF on Zn uptake of seeds and stovers were significant (Table 4). The highest Zn uptake of seeds was found in V_1T_6 (76.36 g ha^{-1}) and the lowest from V_2T_1 (41.23 g ha^{-1}). In case of stover, the highest uptake was found in V_2T_8 (110.80 g ha^{-1}), followed by V_1T_6 (110.20 g ha^{-1}) and V_1T_8 (109.80 g ha^{-1}). The lowest uptake of Zn in stover was obtained from V_1T_1 (49.37 g ha^{-1}). Zinc enriched PM caused utilization of nutrients mainly due to its beneficial effect in mobilizing the native nutrients to increase their availability. The increase in yield may be a reason of higher removal of nutrient due to balanced fertilization [58].

Table 1. Integrated effects of organic manure and IF on N, P, K, Ca, Mg, S and protein contents in seeds and stovers of mungbean

Variety	Treatment	N content (%)		P content (%)		K content (%)		Ca content (%)		Mg content (%)		S content (%)		Seed protein content (%)
		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	
BARI Mung 6	V_1T_1	3.14	1.26	0.40	0.13 i	1.23	1.64	0.18 i	1.64	0.28	0.49 j	0.19	0.10	19.65
	V_1T_2	4.25	1.50	0.56	0.27 cd	1.47	1.89	0.32 e	1.83	0.44	0.66 de	0.28	0.15	26.58
	V_1T_3	3.46	1.33	0.45	0.16 h	1.26	1.69	0.23 h	1.67	0.32	0.54 hi	0.21	0.11	21.65
	V_1T_4	3.80	1.41	0.51	0.26 cde	1.38	1.78	0.36 d	1.87	0.45	0.70 c	0.26	0.14	23.75
	V_1T_5	3.63	1.38	0.48	0.23 ef	1.30	1.72	0.29 g	1.76	0.41	0.59 f	0.23	0.13	22.67
	V_1T_6	4.34	1.52	0.58	0.29 c	1.42	1.84	0.42 b	2.14	0.48	0.78 a	0.26	0.14	27.10
	V_1T_7	3.58	1.37	0.48	0.20 g	1.35	1.75	0.29 g	1.70	0.36	0.56 gh	0.25	0.11	22.38
	V_1T_8	4.12	1.47	0.54	0.26 cde	1.50	1.93	0.40 c	1.99	0.48	0.74 b	0.29	0.16	25.77
BINA Mung 8	V_2T_1	2.78	1.14	0.38	0.17 h	1.28	1.71	0.24 h	1.83	0.22	0.41 k	0.17	0.13	17.38
	V_2T_2	3.79	1.41	0.55	0.36 a	1.54	2.15	0.39 c	2.05	0.36	0.60 f	0.27	0.17	23.71
	V_2T_3	2.97	1.20	0.41	0.19 gh	1.33	1.83	0.27 g	1.93	0.25	0.50 j	0.20	0.14	18.58
	V_2T_4	3.41	1.32	0.47	0.28 c	1.43	1.97	0.39 c	2.11	0.36	0.63 e	0.23	0.16	21.31
	V_2T_5	3.28	1.28	0.46	0.25 de	1.37	1.92	0.34 e	1.98	0.32	0.58 fg	0.22	0.15	20.52
	V_2T_6	3.94	1.48	0.55	0.38 a	1.49	2.08	0.48 a	2.33	0.40	0.70 c	0.26	0.16	24.60
	V_2T_7	3.14	1.24	0.43	0.22 fg	1.40	1.94	0.32 f	1.96	0.28	0.54 i	0.22	0.15	19.65
	V_2T_8	3.66	1.38	0.50	0.32 b	1.58	2.19	0.43 b	2.17	0.41	0.67 d	0.27	0.19	22.85
Level of sig.		ns	ns	ns	**	ns	ns	**	ns	ns	**	ns	ns	ns
LSD (0.05)		-	-	-	0.03	-	-	0.02	-	-	0.02	-	-	-
CV (%)		3.35	4.63	4.02	7.06	3.24	6.33	2.75	5.55	4.55	2.51	5.55	5.72	3.35

*V_1 = BARI Mung-6, V_2 = BINA Mung-8, T_1 = control, T_2 = 100% soil test base (STB) inorganic fertilizer (IF) dose, T_3 = 2.5 t ha^{-1} cowdung (CD) + 85% STB, T_4 = 5 t ha^{-1} CD + 70% STB, T_5 = 1.5 t ha^{-1} poultry manure (PM) + 85% STB, T_6 = 3 t ha^{-1} PM + 70% STB, T_7 = 1.5 t ha^{-1} vermicompost (VC) + 85% STB, T_8 = 3 t ha^{-1} VC + 70% STB, **= Significant at 1% level of probability, ns= non-significant, CV= Coefficient of variation, LSD= Least significant difference.*

Table 2. Integrated effects of organic manure and IF on Zn, Fe, Mn, B and Cu contents in seeds and stovers of mungbean

Variety	Treatment	Zn content (μg g^{-1})		Fe content (μg g^{-1})		Mn content (μg g^{-1})		B content (μg g^{-1})		Cu content (μg g^{-1})	
		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
BARI Mung 6	V_1T_1	32.83 g	18.17 g	108.90	256.30 ef	13.96 fghi	62.33 f	10.67	24.33	13.23	10.00 j
	V_1T_2	35.62 bc	27.83 c	116.20	288.70 b	15.75 b	67.42 f	14.33	28.33	14.10	11.47 fg
	V_1T_3	33.13 fg	22.20 ef	111.40	282.40 b	14.61 cdefg	64.43 f	11.00	27.00	13.60	10.63 i
	V_1T_4	35.23 bcd	23.37 ef	117.30	304.90 a	16.64 a	74.43 e	13.00	28.00	14.43	12.20 de
	V_1T_5	33.77 efg	22.97 ef	110.50	255.80 ef	14.76 cdef	63.95 f	11.67	27.67	13.70	11.07 ghi

Variety	Treatment	Zn content (µg g⁻¹)		Fe content (µg g⁻¹)		Mn content (µg g⁻¹)		B content (µg g⁻¹)		Cu content (µg g⁻¹)	
		Seed	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**
	V_1T_6	36.27 ab	29.53 bc	116.70	300.80 a	16.91 a	76.05 de	14.67	30.67	14.47	12.73 cd
	V_1T_7	34.13 def	22.50 ef	114.00	286.70 b	15.38 bc	65.75 f	11.00	26.67	13.83	10.80 hi
	V_1T_8	37.03 a	32.50 a	119.70	305.10 a	17.24 a	76.70 cde	14.33	29.33	14.60	13.67 a
BINA Mung 8	V_2T_1	33.97 ef	21.87 f	113.70	247.40 g	13.43 i	80.00 cd	10.33	21.67	11.75	11.37 fgh
	V_2T_2	35.23 bcd	27.43 c	118.50	262.80 cde	14.53 defg	85.78 ab	14.33	25.00	12.70	13.00 bc
	V_2T_3	34.40 de	22.67 ef	116.70	260.70 de	13.59 hi	84.97 ab	11.67	22.67	12.08	11.97 ef
	V_2T_4	35.13 bcd	27.07 cd	122.90	267.80 cd	14.73 cdef	86.30 ab	13.33	23.33	13.07	12.77 cd
	V_2T_5	34.63 cde	23.70 ef	115.30	250.40 fg	13.82 ghi	81.42 bc	12.33	23.33	12.28	12.53 cde
	V_2T_6	35.57 bc	28.17 bc	120.90	266.50 cd	14.95 cde	86.54 ab	15.00	26.00	13.30	13.53 ab
	V_2T_7	34.90 cde	24.77 de	117.10	260.70 de	14.32 efgh	85.08 ab	12.00	22.00	12.50	12.27 de
	V_2T_8	35.73 bc	30.43 ab	124.10	270.20 c	15.18 bcd	87.10 a	14.67	25.67	13.47	14.07 a
Level of sig.		**	**	ns	**	*	**	ns	ns	ns	*
LSD (0.05)		1.02	2.35	-	7.47	0.72	4.61	-	-	-	0.60
CV (%)		1.75	5.57	8.04	1.64	2.87	3.60	5.84	3.90	1.19	2.97

*V_1 = BARI Mung-6, V_2 = BINA Mung-8, T_1 = control, T_2 = 100% soil test base (STB) inorganic fertilizer (IF) dose, T_3 = 2.5 t ha^{-1} cowdung (CD) + 85% STB, T_4 = 5 t ha^{-1} CD + 70% STB, T_5 = 1.5 t ha^{-1} poultry manure (PM) + 85% STB, T_6 = 3 t ha^{-1} PM + 70% STB, T_7 = 1.5 t ha^{-1} vermicompost (VC) + 85% STB, T_8 = 3 t ha^{-1} VC + 70% STB, **= Significant at 1% level of probability, *= Significant at 5% level of probability, ns= non-significant, CV= Coefficient of variation, LSD= Least significant difference*

Table 3. Integrated effects of organic manure and IF on N, P, K, Ca, Mg and S uptake in seeds and stovers of mungbean

Variety	Treatment	N uptake (kg ha⁻¹)		P uptake (kg ha⁻¹)		K uptake (kg ha⁻¹)		Ca uptake (kg ha⁻¹)		Mg uptake (kg ha⁻¹)		S uptake (kg ha⁻¹)	
		Seed	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**	**Seed**	**Stover**
BARI Mung 6	V_1T_1	40.18	34.36	5.08	3.62 i	15.77	44.77	2.31	44.63	3.62 i	13.23 i	2.43	2.73
	V_1T_2	77.39	49.58	10.26	9.04 ef	26.74	62.73	5.88	60.44	7.94 cd	21.71 cd	5.16	5.04
	V_1T_3	53.60	38.73	6.92	4.76 h	19.43	49.22	3.51	48.54	5.00 h	15.81 h	3.30	3.25
	V_1T_4	70.89	48.37	9.57	8.93 ef	25.78	61.21	6.66	64.10	8.40 c	24.00 b	4.79	4.75
	V_1T_5	58.84	41.68	7.72	7.02 g	21.11	51.73	4.64	52.97	6.71 fg	17.87 g	3.78	3.99
	V_1T_6	91.41	56.53	12.24	10.78 cd	29.87	69.12	8.92	79.92	10.17 a	29.31 a	5.48	5.22
	V_1T_7	59.96	44.69	7.99	6.38 g	22.55	56.85	4.86	55.22	6.02 g	18.30 fg	4.13	3.72
	V_1T_8	79.20	49.73	10.44	8.89 ef	28.74	65.42	7.74	67.27	9.22 b	25.10 b	5.50	5.50
BINA Mung 8	V_2T_1	33.75	33.36	4.57	4.85 h	15.52	50.00	2.91	53.57	2.67 j	11.87 j	2.07	3.92
	V_2T_2	64.73	48.5	9.44	12.23 b	26.22	74.21	6.66	70.74	6.21 g	20.68 de	4.60	5.76
	V_2T_3	44.68	37.32	6.12	6.02 g	20.05	56.98	4.10	60.06	3.82 i	15.38 h	2.96	4.43
	V_2T_4	59.18	46.22	8.16	9.90 de	24.82	68.98	6.83	73.84	6.20 g	22.16 c	4.05	5.55
	V_2T_5	50.90	42.99	7.08	8.37 f	21.28	64.14	5.21	66.32	5.02 h	19.52 ef	3.42	5.18

Variety	Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		Ca uptake (kg ha^{-1})		Mg uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
	V_2T_6	71.68	52.01	10.07	13.32 a	27.06	72.88	8.80	81.78	7.22 ef	24.75 b	4.80	5.70
	V_2T_7	49.86	40.32	6.87	6.99 g	22.25	63.11	5.03	64.08	4.50 h	17.43 g	3.44	5.03
	V_2T_8	68.76	50.27	9.4	11.75 bc	29.69	79.56	8.02	79.05	7.71 de	24.51 b	5.14	6.98
Level of sig.		ns	ns	ns	**	ns	ns	ns	ns	**	**	ns	ns
LSD (0.05)		-	-	-	1.06	-	-	-	-	0.65	1.32	-	-
CV (%)		5.90	4.68	5.82	7.63	4.33	7.29	4.71	5.50	6.16	3.95	6.23	6.31

*V_1 = BARI Mung-6, V_2 = BINA Mung-8, T_1 = control, T_2 = 100% soil test base (STB) inorganic fertilizer (IF) dose, T_3 = 2.5 t ha^{-1} cowdung (CD) + 85% STB, T_4 = 5 t ha^{-1} CD + 70% STB, T_5 = 1.5 t ha^{-1} poultry manure (PM) + 85% STB, T_6 = 3 t ha^{-1} PM + 70% STB, T_7 = 1.5 t ha^{-1} vermicompost (VC) + 85% STB, T_8 = 3 t ha^{-1} VC + 70% STB, **= Significant at 1% level of probability, ns= non-significant, CV= Coefficient of variation, LSD= Least significant difference*

Table 4. Integrated effects of organic manure and IF on Zn, Fe, Mn, B and Cu uptake in seeds and stovers of mungbean

Variety	Treatment	Zn uptake (g ha^{-1})		Fe uptake (g ha^{-1})		Mn uptake (g ha^{-1})		B uptake (g ha^{-1})		Cu uptake (g ha^{-1})	
		Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
BARI	V_1T_1	42.04 h	49.37 f	139.30	696.70 h	17.87 j	170.00 k	13.66	66.14 gh	16.95 m	27.19 j
Mung 6	V_1T_2	64.80 cd	92.09 b	211.50	955.30 cd	28.65 d	223.40 hi	26.07	93.82 bc	25.67 cd	37.95 ef
	V_1T_3	51.27 g	64.42 de	172.30	821.50 f	22.58 gh	187.70 j	17.05	78.47 f	21.05 ij	30.98 i
	V_1T_4	65.73 c	79.96 c	219.00	1045.00 b	31.06 c	255.20 g	24.23	96.07 bc	26.94 bc	41.81 d
	V_1T_5	54.63 fg	69.04 de	178.80	770.00 g	23.93 fg	192.60 j	18.85	83.21 ef	22.18 ghi	33.30 hi
	V_1T_6	76.36 a	110.20 a	247.30	1124.00 a	35.62 a	284.80 cd	30.89	114.60 a	30.47 a	47.58 b
	V_1T_7	57.12 ef	73.06 cd	191.00	931.30 de	25.75 ef	213.80 i	18.43	86.68 de	23.16 fg	35.13 gh
	V_1T_8	71.09 b	109.80 a	229.70	1032.00 b	33.11 b	258.80 fg	27.52	99.02 b	28.04 b	46.15 bc
BINA	V_2T_1	41.23 h	63.91 e	137.90	722.60 h	16.29 j	234.10 h	12.52	63.32 h	14.25 n	33.22 hi
Mung 8	V_2T_2	60.15 e	94.74 b	201.80	906.20 e	24.81 f	296.00 bc	24.44	86.18 de	21.68 hi	44.86 bc
	V_2T_3	51.74 g	70.57 de	174.90	810.80 fg	20.41 i	264.50 efg	17.56	70.53 g	18.16 lm	37.22 fg
	V_2T_4	60.98 de	94.78 b	213.00	937.10 de	25.55 ef	302.30 ab	23.16	81.70 ef	22.68 gh	44.69 c
	V_2T_5	53.71 fg	79.41 c	178.20	838.70 f	21.41 hi	273.00 def	19.14	78.13 f	19.04 kl	41.97 d
	V_2T_6	64.76 cd	98.97 b	219.80	935.80 de	27.23 de	304.30 ab	27.32	91.18 cd	24.21 ef	47.52 b
	V_2T_7	55.36 fg	80.82 c	185.50	850.10 f	22.70 gh	277.50 de	19.04	71.69 g	19.84 jk	39.97 de
	V_2T_8	67.19 c	110.80 a	233.30	984.00 c	28.55 d	317.30 a	27.57	93.42 bc	25.32 de	51.23 a
Level of sig.		**	**	ns	**	**	**	ns	**	**	**
LSD (0.05)		3.84	7.99	-	42.57	1.84	16.33	-	6.32	1.33	2.58
CV (%)		3.93	5.71	10.06	2.84	4.35	3.86	6.54	4.48	3.56	3.87

*V_1 = BARI Mung-6, V_2 = BINA Mung-8, T_1 = control, T_2 = 100% soil test base (STB) inorganic fertilizer (IF) dose, T_3 = 2.5 t ha^{-1} cowdung (CD) + 85% STB, T_4 = 5 t ha^{-1} CD + 70% STB, T_5 = 1.5 t ha^{-1} poultry manure (PM) + 85% STB, T_6 = 3 t ha^{-1} PM + 70% STB, T_7 = 1.5 t ha^{-1} vermicompost (VC) + 85% STB, T_8 = 3 t ha^{-1} VC + 70% STB, **= Significant at 1% level of probability, ns= non-significant, CV= Coefficient of variation, LSD= Least significant difference*

Although interaction of varieties and different levels of manures along with IF on Fe uptake of seeds was not significant, the Fe content of stovers was significantly varied (Table 4). The highest Fe uptake in seeds was observed in V_1T_6 (247.30 g ha^{-1}) and lowest in V_2T_1 (137.90 g ha^{-1}). For stover, the highest Fe uptake was obtained from V_1T_6 (1124.00 g ha^{-1}) and the lowest was found in V_1T_1 (696.70 g ha^{-1}). The presence of higher microbial and enzymatic activity in PM and VC possibly stimulated the root growth and thus resulted in higher uptake of micronutrients in general by mungbean and iron in particular. Similar findings were reported by Basavaraju [59] who observed that application of VC resulted in significant improvement iron uptake.

The variation was found significant due to combined effects of varieties and different levels of manures along with IF on Mn uptake of seeds and stovers (Table 4). The highest Mn uptake of seeds was found in V_1T_6 (35.62 g ha^{-1}) and the lowest was from the combination of V_2T_1 (16.29 g ha^{-1}). On the other hand, the Mn uptake of stover was maximum in V_2T_8 (317.30 g ha^{-1}) treatment, followed by V_2T_6, V_2T_4 and minimum in V_1T_1 (170.00 g ha^{-1}). Walia and Kier [60] reported that application of organic manures increased the uptake of micronutrients.

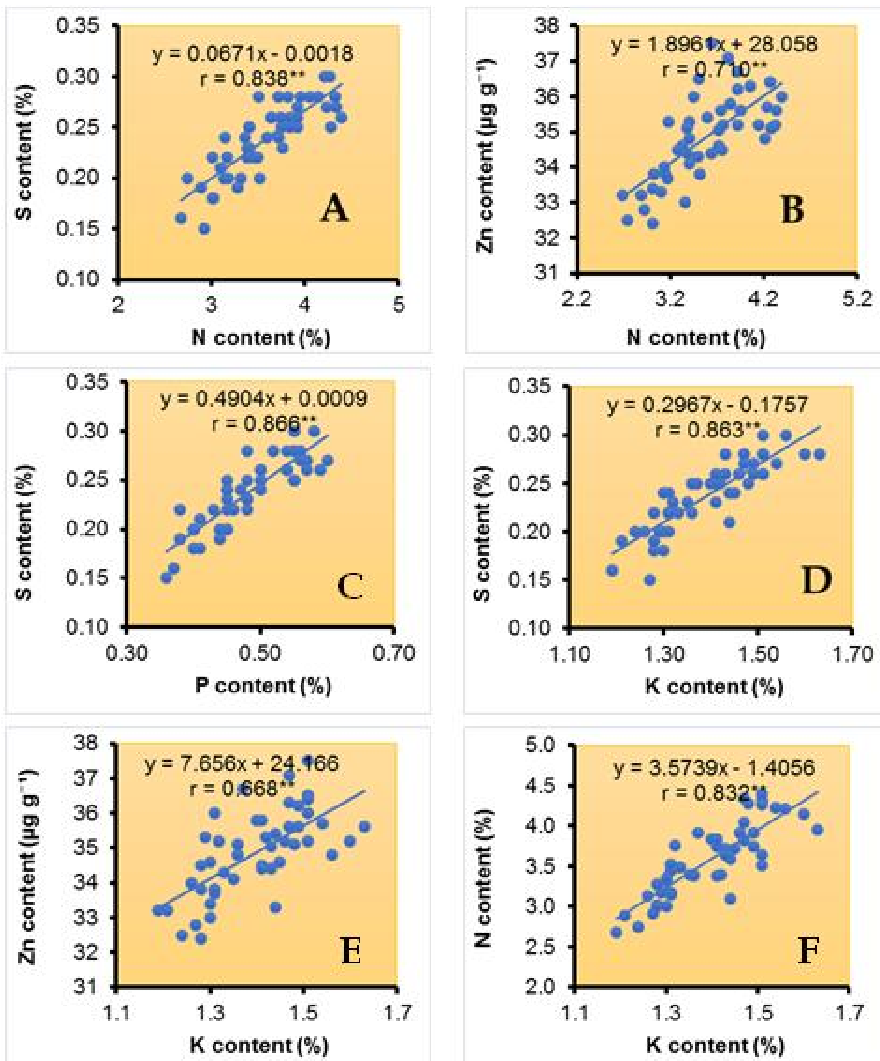

Fig. 1. Correlations and regression equations between N and S content (A), N and Zn content (B), P and S content (C), K and S content (D), K and Zn content (E) and K and N content (F) of mungbean seeds as influenced by integrated nutrient management

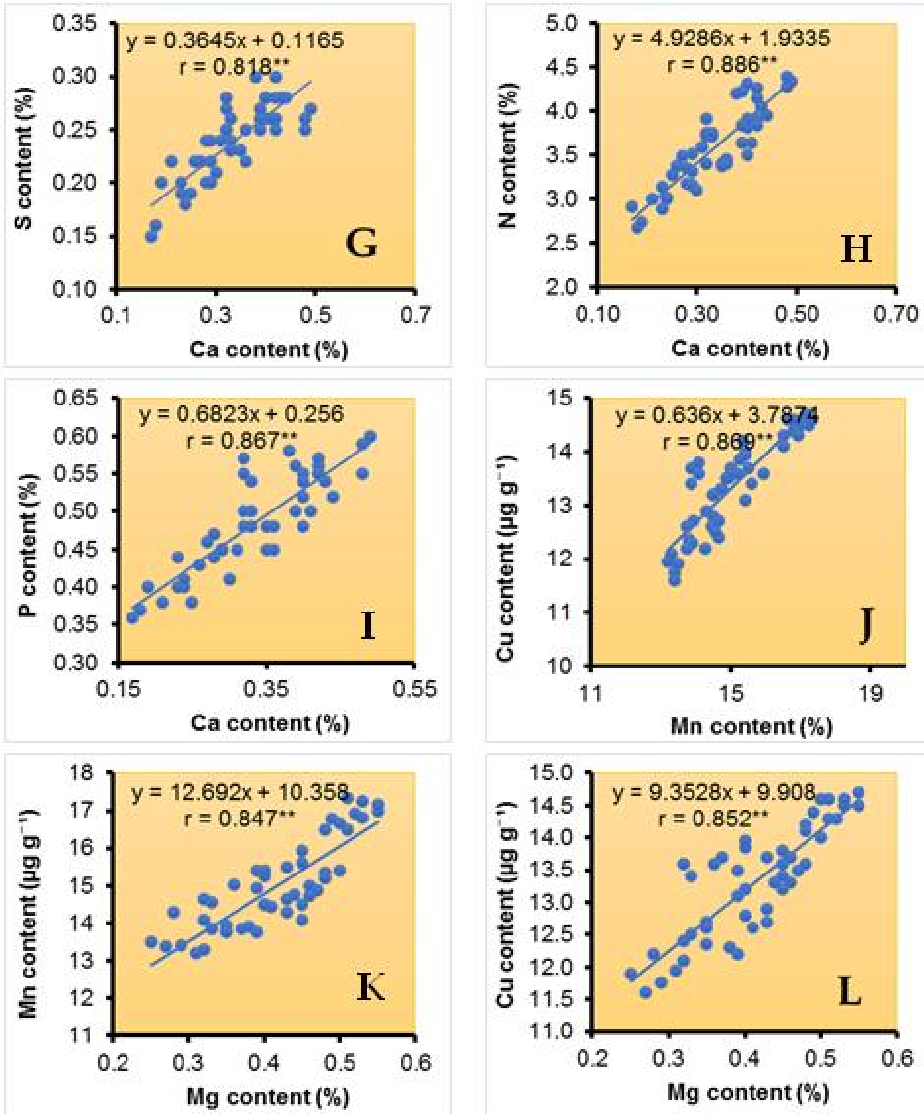

Fig. 2. Correlations and regression equations between S and Ca content (G), Ca and N content (H), Ca and P content (I), Cu and Mn content (J), Mg and Mn content (K) and Mg and Cu content (L) of mungbean seeds as influenced by integrated nutrient management

Although the interaction of varieties and different levels of manure along with IF on B uptake of seeds was not significant, the B uptake of stovers varied significantly (Table 4). The highest B uptake was found from V_1T_6 (30.89 g ha^{-1}) and lowest from V_2T_1 (12.52 g ha^{-1}). Similarly, the highest and lowest B uptake of stover was 114.60 g ha^{-1} (V_1T_6) and 63.32 g ha^{-1} (V_2T_1). Application of boric acid with PM might be the reason for higher uptake of B. Akanini and Ojenini [61] observed that PM increased uptake of macro and micro nutrient due to increased organic matter.

The combined effects of variety and different levels of manures along with IF on Cu uptake of seeds and stover was significant. The highest Cu uptake in seeds was found in V_1T_6 (30.47 g ha^{-1}) and lowest from V_2T_1 (14.25 g ha^{-1}). Again, the highest Cu uptake in stover was found in V_2T_8 (51.23 g ha^{-1}) and lowest from V_1T_1 (27.19 g ha^{-1}). Walia and Kier [60] reported that application of organic manures increased the uptake of micronutrients. Cheng et al. [62] also reported that micronutrients uptake and content in Sudan grass increased with the increased rate of VC application.

3.3 Correlation and Regression Studies among the Nutrient Contents of Seed

The correlation between the mineral contents in seeds of mungbean have been found out (Figs. 1 & 2). Highly significant positive correlation were found between N and S (r = 0.838**), N and Zn (r = 0.710**), P and S (r = 0.866**), K and S (r = 0.863**), K and Zn (r = 0.668**), K and N (r = 0.832**). It is shown from the Fig. 2 that there was a direct significant and positive relationship between Ca and S (r = 0.818**), Ca and N (r = 0.886**), Ca and P (r = 0.867**), Mn and Cu (r = 0.869**), Mg and Mn (r = 0.847**), Mg and Cu (r = 0.852**). The results are in conformity with those of Zacharias et al. [63]. Selection of a desired mineral could improve the level of another mineral if there is a positive correlation between the two [64].

3.4 Principle Component Analysis

The patterns of variation were evaluated by PCA using two mungbean varieties and based on protein and 11 mineral traits. From the scree plot of eigenvalues of the PCA (Fig. 3) it can be seen that first three components for protein and 11 mineral traits explained 88.90% of the total variance (Table 5). About 67.70% of the variation was explained by the first principal component (PC1). Protein, N and P had the highest contribution in PC1. The second principal component (PC2) was highly dependent on Fe, K and Cu and accounted for 14.10% of the variability. Cu content of seed was negatively correlated with the second component (Fig. 3).

The third principal component (PC3) accounted for 7.10% of total variability, and Fe, B and Zn.

Table 5. Cumulative percentages of variance explained by the first 3 principal components (PCs) of mungbean seed for protein and mineral contents

Variable	PC1	PC2	PC3
Protein (%)	0.329	0.178	0.034
N (%)	0.329	0.178	0.034
P (%)	0.327	0.012	-0.033
K (%)	0.254	-0.447	-0.013
Ca (%)	0.284	-0.361	-0.098
Mg (%)	0.324	0.206	0.052
S (%)	0.320	-0.013	-0.065
Zn (µg g^{-1})	0.274	-0.197	-0.309
Fe (µg g^{-1})	0.088	-0.454	0.817
Mn (µg g^{-1})	0.288	0.268	0.217
B (µg g^{-1})	0.300	-0.220	-0.316
Cu (µg g^{-1})	0.259	0.446	0.265
Eigenvalue	8.12	1.70	0.848
Variability (%)	67.70	14.10	7.10
Cumulative (%)	67.70	81.80	88.90

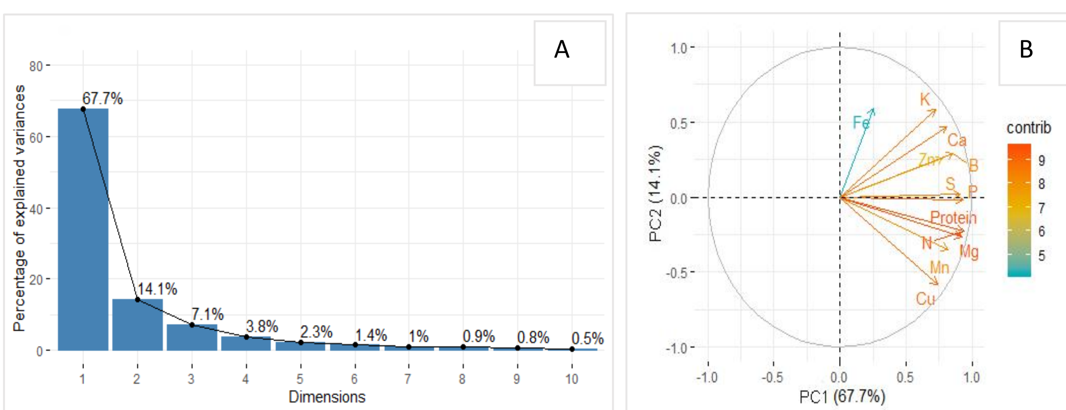

Fig. 3. Scree plot (A) and Biplot (B) of protein and different mineral contents of mungbean seed

content had the highest contribution in PC3. Fe content of seed was negatively correlated with the third component (Fig. 3). The first two principal components were important accounting for approximately 81.80% of the total variability

4. CONCLUSION

Based on the findings of the present study, it was observed that different treatment performed differently in respect of nutrient contents and uptake of seed and stover, and protein contents. The results of the experiment indicated that BARI Mung-6 performed better than BINA Mung-8 in case of most of the nutrient contents and their uptake. Application of 3 t ha^{-1} poultry manure along with 70% IF showed better performance on protein and nutrient contents and their uptake by mungbean. But application of 3 t ha^{-1} vermicompost along with 70% IF provided almost similar results with the sole application of IF improving quality yield and protein and nutrient contents of mungbean. From the above experimental findings, it is concluded that BARI Mung-6 appeared as the best variety and poultry manure @ 3 t ha^{-1} along with 70% IF should be applied for getting better nutritional mungbean seed with higher protein contents under the agroclimatic condition of BARI.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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