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Research Article

Effects of different nutrient sources on seed germination and early growth of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) and brinjal (*Solanum melonjena* L.)

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Abstract

The population and food demand are growing at the same rate. Properly applying fertilizers is important to this endeavor, as it is critical in increasing growth, yields, and quality. The filter paper seed germination bioassay will serve as a better alternative to study the direct impact of fertilizers on seed germination because, in soil or culture medium-based studies, various other factors also influence germination and growth. The present study investigated the effect of seven different fertilizers: mineral (Urea, DAP, and combined NPK), organic (Vermicompost + Poultry, Pond slurry, Farmyard manure), and organomineral (Pond slurry + Poultry + Mineral) having four different concentrations (110, 220, 330, 440 mg/L) on seed germination and seedling growth of brinjal and cluster bean while the double distilled water served as blank. Various parameters were recorded, such as the seedling's relative germination ratio, shoot length, root length, fresh weight, and dry weight. Among different fertilizers, organic fertilizers give the best-suited results at 440 mg/L, while mineral fertilizers above 110 mg/L inhibited germination and seedling growth. The best-suited fertilizer combination was organomineral, with a concentration of 220 mg/L. Furthermore, regression analysis depicted a stronger correlation between growth parameters and the N, P, and K content of different fertilizers. This study suggests that higher doses of fertilizers sometimes leads to inhibition of growth and yield. Additionally, organomineral fertilizer served as better alternative because they blend both organic and inorganic nutrients.

Keywords: Germination bioassay, Inorganic fertilizers, Organic fertilizers, Seed germination

INTRODUCTION

In modern agriculture, it is highly important to use sustainable and eco-friendly practices to meet the rising global demand for food (Food and Agriculture Organization, 2019). Properly applying fertilizers is important to this endeavor, as it plays a critical role in increasing crop yields and quality. Fertilizers are the sole source of providing macro and micronutrients to crops for sustaining growth and yield as well as soil fertility (Dhaliwal *et al.,* 2019). These nutrients are essential for various life processes such as photosynthesis, energy production, etc., and are crucial for the growth and development of the plant (Ahmed *et al.,* 2020). In addition to better plant growth and development, fertilizers are crucial in maintaining soil health through improved pH, soil structures, microbiota, etc. (Singh and Ryan, 2015). Insufficient fertilization may result in economic losses for farmers and low soil fertility since it limits nutrition to plants, reducing yield and food availability (Li *et al.,* 2022 and Goud *et al.,* 2022).

Historically, India's agriculture systems relied on organic manures as nutrient sources (Verma *et al.,* 2021). The use of inorganic fertilizers became highly popular in the Green Revolution at the end of the nineteenth century. Their use in agriculture boosts yield and creates a spark in the field of agriculture (Zhen *et al.,* 2014). Nonetheless, they remain critical for global food security, and their negative consequences cannot be overlooked, especially as sustainable agriculture becomes increasingly important (Wani *et al.,* 2021 and Kang *et al.,* 2022). Due to the higher application of chemical fertilizers in fields, they change into inert forms and the plant cannot absorb the resulting compounds (Alalaf *et al.,* 2023). These excess fertilizers carried out by water and deposited into water bodies, causing various problems like pollution, eutrophication, and algal blooms (Khan and Mohammad, 2014 and Srivastav, 2020). For a long, organic fertilizers have been known to improve various physical characteristics of the soil, like reduced bulk density and alkalinity, improved soil porosity, aeration, water holding capacity, etc. (Meena *et al.,* 2023). With increasing organic matter by organic manures, humus content also increases, which results in various changes in the biological properties of the soil and allows beneficial microbes and other soil organisms to grow (Tiwari *et al.,* 2023 and Didawat *et al.,* 2023). Organic fertilizers improve soil fertility and boost output by increasing soil carbon, nitrogen, and other nutrients while being eco-friendly and cheap (Elidar, 2018 and Singh *et al.,* 2020).

According to Singh *et al.* (2019), maintaining soil health and increasing crop production solely through organic nutrient sources will require significant organic fertilizer at regular intervals. In contrast, using inorganic fertilizers alone may result in enhanced crop yields in a short period. However, it has a prominent effect on soil health, causing soil organic matter loss and affecting the natural environment (Li *et al.,* 2020). Due to the negative consequences of applying inorganic or organic fertilizers separately, a mixture of organic manure and inorganic fertilizers has emerged as a feasible option for improving soil health and productivity. As a result, combining inorganic and organic fertilizers improve soil productivity and fertility in less expensive ways while minimizing the negative effects that chemical fertilizers can have (Ayeni and Ezeh, 2017 and Farid *et al.,* 2023). Organomineral fertilizers are preferable options because they contain both organic (slow-releasing) and inorganic (fast-releasing) components that increase yield while maintaining soil fertility (Smith *et al.,* 2020).

Plant species rely on seeds to survive. Seed germination is the first and crucial stage in optimizing crop yield (Wolny *et al.,* 2018). The effect of various fertilizers like vermicompost, agricultural compost, sewage sludge, mineral fertilizers, etc. was studied by the scientific community on seed germination, seedling growth, and development (Sarma and Gogoi, 2015 and Mog *et al.,* 2017). When evaluating the effect using soil or media, various other factors also interfere with seed germination and seedling emergence. Assessing the direct relationship between fertilizers and growth parameters is difficult in this scenario. So, filter paper seed germination bioassay is the best alternative for establishing an obvious correlation between fertilizers, germination, and growth parameters of seeds (Eyheraguibel *et al.,* 2008 and Pan *et al.,* 2022).

Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) and brinjal (*Solanum melonjena* L.) are grown at a larger scale in India. Cluster bean is a highly important legume crop and India accounts for approx. 80 % of global production (Bhatt *et al.,* 2017). Behind potatoes and tomatoes, brinjal is the third most extensively produced crop in the Solanaceae family and Asia accounts for almost 90% of global output, primarily China and India (Wei *et al.,* 2020). The present study aimed to evaluate the efficacy of different nutrient sources like Farmyard manure (FM), Poultry + Vermicompost (PV), Pond slurry (PO), one organomineral fertilizer (OM), and three inorganic fertilizers used were Diammonium phosphate (DAP), Urea (U) and combined mineral fertilizer (CM) on cluster bean and brinjal.

MATERIALS AND METHODS

Study material and treatments

Two crop species Brinjal (*Solanum melonjena* L.) and Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) were used for seed germination bioassay. Both the crop species follow the recommendations of the Organisation for Economic Co-operation and Development (2006) for seed germination and early growth testing. The crops were widely grown in the area as crops. The seeds were obtained from Indian Farmers Fertiliser Cooperative Limited, New Delhi. Before proceeding to germination bioassay, seeds were surface sterilized in a 14% sodium hypochlorite solution for 10 minutes and washed with double distilled water. All fertilizers were ground into powdered form, and stock solutions were prepared at 5 g/L for further use.

A total of 7 organic, organomineral, and inorganic fertilizers having a definite ratio of N, P, and K content were selected to assess their potential and efficacy. The three organic fertilizers used were Farm yard manure (0.8:0.4:0.4), Poultry + Vermicompost (1.6:1.2:1.5), Pond slurry (1.8:1.9:1.2), one organomineral fertilizer (12:9.2:9.8) and three inorganic fertilizers used were Diammonium phosphate (18:46:0), Urea (46:0:0) and combined mineral fertilizer (21.3:15.3:16.6). Inorganic fertilizers were obtained from Indian Farmers Fertiliser Cooperative limited, New Delhi. The organomineral fertilizer was prepared from organic (pond slurry, poultry) and inorganic (N, P, and K) fractions, while organic fertilizers were collected from the rural areas of Kurukshetra, Haryana.

Seed germination bioassay

Aqueous solutions of the seven different fertilizers were prepared in deionized water at four varying concentrations: 110, 220, 330, and 440 mg/L while the deionized water served as blank. According to the standard germination protocol suggested by American Society for Testing Materials (2003) and Pan *et al.* (2022), 10-20 seeds of particular crop species were placed into a Petri plate with filter paper, and 5 ml of each fertilizer solution was added through syringe filtration into the petri dish. After covering the Petri dishes, they were placed in the growth chambers in triplicates with a temperature of 25°C and 80% humidity in total light conditions in accordance with the test crop species. If necessary, water loss from the Petri dishes was regularly monitored and added. During the test, fertilizer absorption and degradation were minimal. The root and shoot lengths were measured and their fresh weight, dry weight (oven-dried), and the relative seed germination percentage were determined. The average incubation period for both the crops was 12 days.

Statistical analysis

All the statistical analyses were conducted using software R version 4.3.1. Firstly, to assess the variance among different fertilizers, ANOVA was performed using the package 'stats' (Table 6). Subsequently, the data was visualized to see the differences in means alongside their corresponding standard deviations. Furthermore, regression equations were derived to understand the correlation between N, P, and K content present in fertilizers and different growth parameters. This was achieved using the same 'lm' function within the package 'stats'. R-squared values and p-values were then computed to evaluate the strength and significance of the relationships identified.

RESULTS AND DISCUSSION

Relative germination ratio

Overall, organic fertilizers promoted seed germination rate compared to control, while organomineral and inorganic fertilizers inhibited seed germination in their higher concentration. In brinjal seeds, inorganic fertilizers inhibited germination compared to control, while in the case of cluster bean, a lower concentration of 110 mg/L promoted germination while a higher concentration showed inhibitory effects (Table 1). The highest relative germination ratio (RGR) in brinjal (103%) was observed with organic fertilizer (FM) at a concentration of 440 mg/L and organomineral fertilizer (OM) at 220 mg/L. For cluster bean, the highest RGR (112.5%) was achieved with organic (PO) and organomineral fertilizer (OM), both at a concentration of 330 mg/L. Cluster beans at 110 mg/L concentration of urea also showed a higher RGR value (112.5%). Urea, the most abundantly used fertilizer in our cropping system, significantly affects seed germination, but its long-term usage negatively impacts soil (Oli *et al.,* 2024). The lowest relative germination ratios were recorded in the higher concentration of mineral fertilizers. Similar findings were also reported that poultry, vermicompost, and farmyard manure results in better seed germination in mulberry and certain other crops (Wani *et al.,* 2017 and Rasool *et al.,* 2023). Organic and organomineral fertilizers provided more satisfactory results because having organic carbon fraction, micronutrients, and other micronutrients that are essential for seed to grow (Abd-El-Hamid and Bugaev, 2020 and Shafique *et al.,* 2021).

Effect of varying fertilizer concentration on various growth parameters

The present study identified ideal fertilizer concentrations to promote shoot and root growth. Shoot and root length in different fertilizer concentrations were compared with the control, which had double distilled water. Different fertilizer concentrations show a significant ($p<0.001$) effect on shoot and root promotion. In brinjal seeds, organic fertilizers (FM, PV and PO) promoted shoot and root length with increasing concentrations. Among organic fertilizers, the highest promotion rate was observed at 440 mg/L concentration of PO with 50.4% in shoot length (1.76 cm) and 45% root length (8.24 cm) promotion compared to control (1.17 cm shoot length and 5.68 cm root length) (Fig.1 a-c & h). Organomineral fertilizer served as the most effective fertilizer at 220 mg/L concentration with 53.8% promotion in the shoot length (1.8 cm) and 72.1% in the root length (9.78 cm) compared to control (Fig.1 d). No information regarding the study of pond slurry as fertilizer was reported, while some workers suggested that sewage sludge is a potential source of nutrients for plants. Studies carried out by Rodrigues *et al.* (2021) on soybeans suggested that sewage sludge-based organic fertilizer results in better growth parameters, increased no. of pods, nodulations and higher accumulation of N, P, and K. Jannat *et al.* (2023) reported that integrated application of vermicompost in brinjal results into increased plant height, no. of fruits/plant, fruit weight, other physiological and biochemical parameters. Among inorganic fertilizers, DAP and Urea at 110 mg/L concentration showed promotion in shoot and root length, while their higher concentration inhibited shoot and root growth. The highest promotion rate among inorganic fertilizers was observed at 220 mg/L concentration of combined mineral fertilizer, with 36.7% promotion in shoot length (1.6 cm) and 41.5% in root length (8.04 cm) compared to control (Fig. 1 e-g). In the soil, urea produces ammonia and carbon dioxide on hydrolysis, followed by a reduction in nitrates and nitrites by soil microbes. As ammonia is toxic in nature, excessive amounts will inhibit seed germination and seedling growth (Shilpha *et al.,* 2023). Combined mineral fertilizers were proven to be better because having three major macronutrients (N, P, and K). In addition to DAP, combined mineral fertilizer contains potassium which activates various enzymes involved in metabolic processes essential for seed germination, such as the breakdown of stored food reserves and the formation of growth regulators; similar findings were also reported by Rawat *et al.* (2016).

In cluster bean seeds (Fig.2 a-h), farmyard manure promoted shoot and root length with increasing concentration of the fertilizer. Among organic fertilizers, the

Table 1. Data showing the effect of varying concentrations of different organic, inorganic and organomineral fertilizers on relative germination ratio, fresh and dry weight of brinjal and cluster bean seedlings

	Brinjal			Cluster beans		
Treat-ments	**Relative germina-tion ratio**	**Fresh weight (in mg)**	**Dry weight (in mg)**	**Relative germina-tion ratio**	**Fresh weight (in mg)**	**Dry weight (in mg)**
FMC1	100	25.06±0.36	1.58±0.04	100	157.8±3.27	15.44±0.35
FMC2	103	26.58±0.37	1.74±0.08	100	159.8±2.38	16.68±0.37
FMC3	103	28.32±0.41	1.88±.04	100	170.8±4.32	17.92±0.67
FMC4	103	29.78±0.26	2.06±.05	100	219±2.54	21.14±0.69
PVC1	84.48	25.7±0.23	1.88±0.04	107.5	195.2±3.96	18.7±0.31
PVC2	84.48	28.9±0.39	2.02±0.13	100	175.2±8.40	16.92±0.37
PVC3	86.18	29.74±0.31	2.06±0.05	100	206.8±5.31	20.34±0.32
PVC4	103	30.2±1.03	2.28±0.1	87.5	231.4±5.72	23.3±0.42
POC1	84.48	27.02±0.13	1.84±0.05	112.5	164±4.41	15.46±0.40
POC2	100	28.68±0.43	2.28±0.08	107.5	173±2.91	19.4±1.14
POC3	94.82	30.24±0.47	2.42±0.13	112.5	214.2±3.56	21.34±0.42
POC4	87.94	33.26±0.77	3.04±0.11	100	239.2±3.76	26.12±0.95
OMC1	91.36	28.7±1.39	2.28±0.08	100	232±4.94	23±0.58
OMC2	103	38.12±1.34	3.1±0.1	100	254±4.06	24.16±0.27
OMC3	93.11	30.4±0.65	2.4±0.1	112.5	218±13.3	21.6±0.28
OMC4	93.11	26.98±0.22	1.84±0.05	91.2	200±18.70	22.54±0.49
DC1	99.94	26.12±0.79	1.8±0.07	112.5	181±10.14	22.06±0.44
DC2	87.94	16.64±0.47	1.6±0.07	87.5	159.8±6.05	16.88±0.35
DC3	77.59	11.4±0.99	1.24	78.7	135±5.74	15.36±0.43
DC4	0	0	0	0	0	0
UC1	86.18	25.42±0.49	2±0.07	112.5	189.2±14.25	20.16±0.84
UC2	72.42	11.2±0.52	1.6±0.07	100	157.8±4.76	18.92±0.43
UC3	0	0	0	66.2	135±5.78	17.78±0.49
UC4	0	0	0	0	0	0
CMC1	87.94	26.82±0.47	1.48±0.08	107.5	222.8±1.78	22.58±0.54
CMC2	100	32.86±0.56	2.6±0.14	100	238±4.56	28.24±0.40
CMC3	87.94	23.7±0.72	1.9±0.07	87.5	155.2±4.65	18.6±0.29
CMC4	0	0	0	0	0	0
CON-TROL	-	24.86±0.23	1.5±0.1	-	151.8±4.20	15.04±0.26

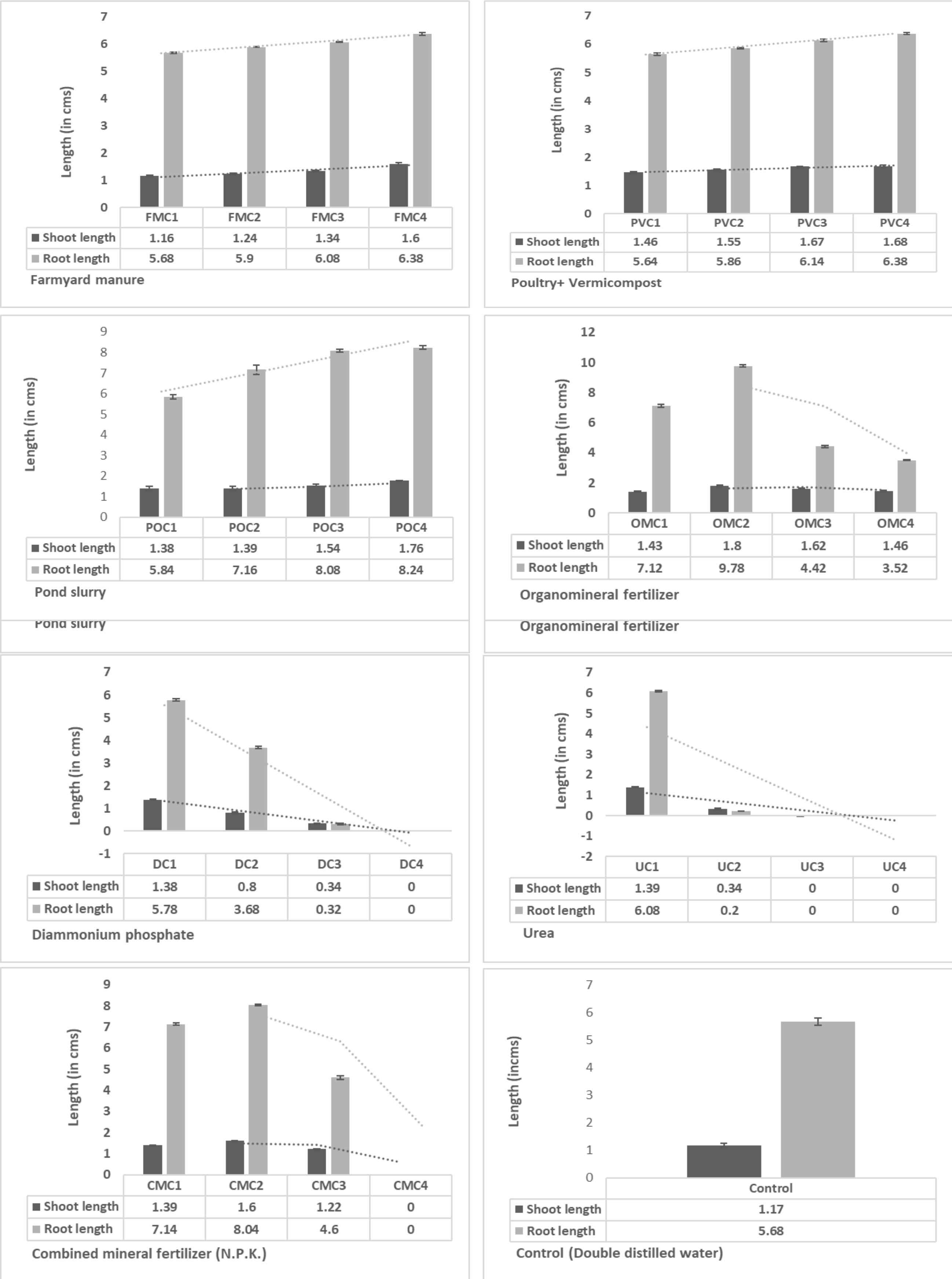

Fig. 1 (a-h): *Seven tested fertilizers showing effect on root and shoot elongation in brinjal seeds (Grey bars =root length, black bars =shoot length). All data were statistically analysed by ANOVA (P< 0.001). The error bars showing the standard deviation of all data.*

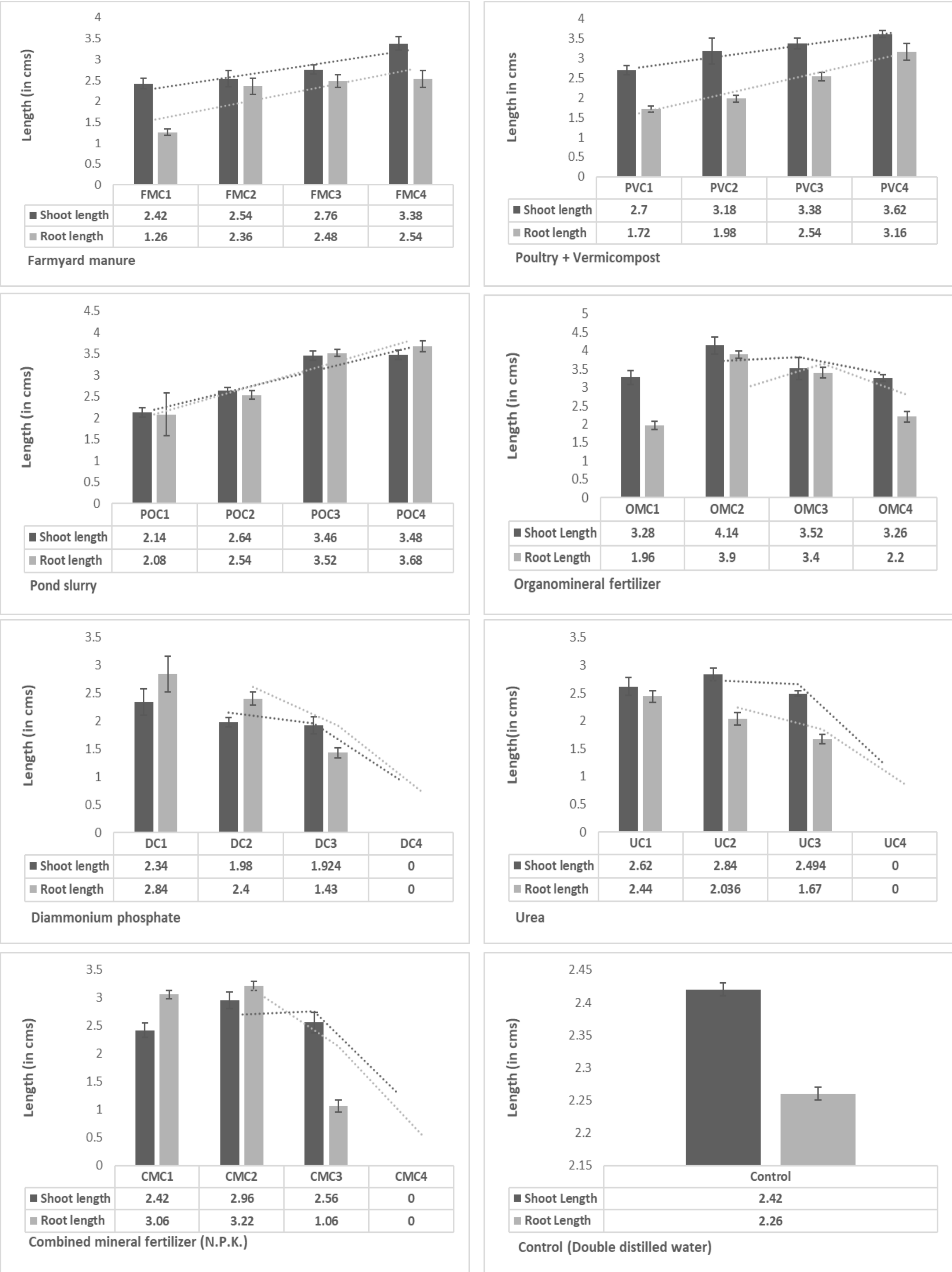

Fig. 2 (a-h). *Seven tested fertilizers showing effect on root and shoot elongation in cluster bean seeds (Grey bars = root length, black bars =shoot length). All data were statistically analysed by ANOVA (P< 0.001). The error bars showing the standard deviation of all data.*

highest promotion rate was observed at 440 mg/L concentration of PV with 49.5% promotion in shoot length (3.62 cm), while maximum promotion in root length (3.68 cm) in organic fertilizers was observed at 440 mg/L concentration of PO with 62.86% promotion compared to control (2.42 cm shoot length and 2.26 cm root length). No inhibition on shoot and root length promotion was observed with increasing concentration compared to control. Organomineral fertilizer served as the most effective fertilizer at 220 mg/L concentration with 71 % promotion in the shoot length (4.14 cm) and 72.5% in the root length (3.9 cm). Organic fertilizers seem to be a better source of nutrients in terms of plant growth and reducing soil pollution. Studies suggested that poultry manure-based organomineral fertilizers improve seed germination, seedling growth, and yield by maintaining a steady supply of nutrients to plants and reducing the flux of nutrients to the environment (Aitbayev *et al.,* 2018 and Mažeika *et al.,* 2021). Among inorganic fertilizers, DAP and Urea at 110 mg/L concentration promoted shoot and root length while their higher concentration showed toxic effects in shoot and root growth. The highest promotion rate among inorganic fertilizers was observed at 220 mg/L concentration of combined mineral fertilizer with 22.3% promotion in shoot length (2.96 cm) and 42% in root length (3.22 cm) compared to control. Combined N, P, and K fertilizer with other nutrient sources on cucumber gives promising results in promoting growth and yield (Wang *et al.,* 2023). Combined mineral fertilizer seems to be better than urea and DAP alone because inadequate levels of potassium can lead to reduced germination rates and seedling growth (Thornburg *et al.,* 2020). Therefore, ensuring adequate nutrient availability is crucial for improving seed germination and successive seedling growth.

In addition to root length and shoot length, other observed growth parameters included the seedling's fresh weight and dry weight. As the concentration of organic fertilizers increased, the fresh and dry weight of the seedling increased as well; the opposite was seen with inorganic fertilizers (Table 1). The highest fresh weight (38.12 mg) and dry weight (3.1 mg) in brinjal was recorded with organomineral fertilizers at a concentration 220 mg/L. Similarly, higher fresh weight (254 mg) and dry weight (24.1 mg) in cluster beans was reported with organomineral fertilizers at the same concentration. Semida *et al.* (2015) worked on the effect of organomineral fertilizers on brinjal and observed that organomineral fertilizers showed increased seedling growth, photosynthetic efficiency, and seedling anatomy. Studies recorded that organic and mineral fertilizers improve seedling vigor, dry weight, and other growth parameters (Angadi *et al.,* 2017). Higher concentrations of fertilizers may affect seed germination, seedling emergence, and growth (Erşahin *et al.,* 2017). So, it is highly recommended that the optimum concentration of fertilizers be used to improve growth and yield.

Optimizing suitable concentrations of fertilizers for growth and development

For both crop species, ideal concentrations of FM, PV, and PO were more than 440 mg/L, whereas in the case of organomineral fertilizers, the optimal concentration was 220 mg/L. Brinjal and cluster bean concentrations below 110 mg/L of Urea and DAP seem optimal, while concentrations below 220 mg/L were optimal for combined mineral fertiliser. Apart from organic fertilizers, overfertilization was observed with other fertilizer types. Studies carried out by Shaji *et al.* (2021) showed that manures are generally used as a source of N, P, and K, also contains other macro and micronutrients. Or-

Table 2. Regression equations analyzing the effect of N, P, and K content in various organic, inorganic and organomineral fertilizers on shoot length in brinjal seedlings

Shoot elongation in brinjal				
Types	Fertilizers	N	P	K
Organic	Farmyard manure	$y=.058x^2-0.094x+1.205$ ($R^2=.87$)	$y=0.413x^2-0.251x+1.205$ ($R^2=.87$)	$y=.23x^2-0.188x+1.205$ ($R^2=.87$)
	Poultry+ Vermicomposting	$y=-0.006x^2+.10x+1.295$ ($R^2=.71$)	$y=0.010x^2+0.13x+1.295$ ($R^2=.71$)	$y=0.006x^2+0.10x+1.295$ ($R^2=.71$)
	Pond slurry	$y=0.008x^2-0.036x+1.42$ ($R^2=.88$)	$y=0.007x^2-0.034x+1.42$ ($R^2=.88$)	$y=0.017x^2-0.052x+1.42$ ($R^2=.88$)
Organomineral	OMF	$y=-0.0006x^2+.04x+1.012$ ($R^2=.72$)	$y=-0.001x^2+.053x+1.012$ ($R^2=.72$)	$y=-0.0009x^2+.05x+1.012$ ($R^2=.72$)
Inorganic	Diammonium phosphate	$y=0.00015x^2-.038x+1.205$ ($R^2=.98$)	$y=0.00002x^2-.015x+1.205$ ($R^2=.98$)	NA
	Urea	$y=0.0001x^2-0.034x+2.873$ ($R^2=.99$)	NA	NA
	CMC (N.P.K.)	$y=-0.00064x^2+0.056x+0.402$ ($R^2=.99$)	$y=-0.001x^2+.079x+0.402$ ($R^2=.99$)	$y=-0.001x^2-0.072x+0.402$ ($R^2=.99$)

Table 3. Regression equations analyzing the effect of N, P, and K content in various organic, inorganic and organomineral fertilizers on root length in brinjal seedlings

Root elongation in brinjal				
Types	**Fertilizers**	**N**	**P**	**K**
Organic	Farmyard manure	$y=0.025x^2+0.14x+5.540$ ($R^2=0.93$)	$y=0.183x^2+0.38x+5.540$ ($R^2=0.93$)	$y=0.10x^2+0.29x+5.540$ ($R^2=0.93$)
	Poultry+ Vermicomposting	$y=0.001x^2+0.127x+5.405$ ($R^2=0.91$)	$y=0.002x^2+0.165x+5.405$ ($R^2=0.91$)	$y=0.001x^2+0.127x+5.405$ ($R^2=0.91$)
	Pond slurry	$y=-0.06x^2+1.09x+3.85$ ($R^2=0.98$)	$y=-0.06x^2+1.04x+3.85$ ($R^2=0.98$)	$y=-0.14x^2+1.58x+3.85$ ($R^2=0.98$)
Organomineral	OMF	$y=-0.002x^2+0.080x+6.955$ ($R^2=0.78$)	$y=-0.004x^2+0.105x+6.955$ ($R^2=0.78$)	$y=-0.004x^2+0.099x+6.955$ ($R^2=0.78$)
Inorganic	Diammonium phosphate	$y=0.001x^2-0.21x+9.845$ ($R^2=0.95$)	$y=0.0001x^2-0.084x+9.845$ ($R^2=0.95$)	NA
	Urea	$y=0.0005x^2-0.181x+.135$ ($R^2=0.94$)	NA	NA
	CMC(N.P.K.)	$y=-0.002x^2+0.187x+4.285$ ($R^2=0.98$)	$y=-0.004x^2+0.26x+4.285$ ($R^2=0.98$)	$y=-0.004x^2+0.24x+4.285$ ($R^2=0.98$)

Table 4. Regression equations analyzing the effect of N, P, and K content in various organic, inorganic and organomineral fertilizers on shoot length in cluster bean seedlings

Shoot elongation in cluster beans				
Types	Fertilizers	N	P	K
Organic	Farmyard manure	$y=0.23x^2-0.69x+2.90$ ($R^2=0.84$)	$y=1.65x^2-1.85x+2.90$ ($R^2=0.84$)	$y=0.92x^2-1.39x+2.90$ ($R^2=0.84$)
	Poultry+ Vermicomposting	$y=-0.01x^2+0.34x+2.17$ ($R^2=0.86$)	$y=-0.03x^2+0.44x+2.17$ ($R^2=0.86$)	$y=-0.01x^2+0.34x+2.17$ ($R^2=0.86$)
	Pond slurry	$y=-0.03x^2+0.54x+1.08$ ($R^2=0.91$)	$y=-0.02x^2+0.52x+1.08$ ($R^2=0.91$)	$y=-0.06x^2+0.79x+1.08$ ($R^2=0.91$)
Organomineral	OMF	$y=-0.001x^2+0.10x+2.3$ ($R^2=0.57$)	$y=-0.002x^2+0.13x+2.3$ ($R^2=0.57$)	$y=-0.002x^2+0.12x+2.3$ ($R^2=0.57$)
Inorganic	Diammonium phosphate	$y=-0.0009x^2+0.063x+1.37$ ($R^2=0.91$)	$y=-0.0001x^2+0.024x+1.37$ ($R^2=0.91$)	NA
	Urea	$y=-0.0001x^2+0.002x+2.89$ ($R^2=0.95$)	NA	NA
	CMC(N.P.K.)	$y=-0.0013x^2+0.124x+0.07$ ($R^2=0.89$)	$y=-0.002x^2+0.173x+0.07$ ($R^2=0.89$)	$y=-0.0021x^2+0.159x+0.07$ ($R^2=0.89$)

ganic manures have a salutary effect on soil fertility, improving soil structure and plant growth. Poultry manure had higher nutrient content in comparison to other types (Adekiya *et al.,* 2020). Inorganic fertilizers provide necessary elements essential for germinating and establishing the seedling, which is one of the crucial steps in the life cycle of a plant (Dhaliwal *et al.,* 2019). Their employment in agriculture boosts output, but their inefficient use negatively influences environmental quality and soil productivity, posing serious environmental concerns (Dar *et al.,* 2021).

Optimal concentration of the macro and micronutrients in the soil is essential for the growth of the plants and soil fertility. However, inhibitory effects may also be seen in most of the crops when these elements increase beyond permissible limits (Shrivastav *et al.,* 2020). Nutrient availability in the soil also affects the pH, which plays a crucial role in the germination and growth of seed.

Regression analysis of nutrient content and their effect on shoot and root elongation

Regression analysis is frequently used to evaluate the impact of various fertilizers and their varied concentrations on growth metrics. Regression models are generally used to forecast predicted growth parameters at

Table 5. Regression equations analyzing the effect of N, P, and K content in various organic, inorganic and organomineral fertilizers on root length in cluster bean seedlings

Root elongation in cluster beans				
Types	Fertilizers	N	P	K
Organic	Farmyard manure	$y=-0.33x^2+1.92x-0.13$ ($R^2=0.88$)	$y=-2.38x^2+5.13x-0.13$ ($R^2=0.88$)	$y=-1.34x^2+3.85x-0.13$ ($R^2=0.88$)
	Poultry+ Vermicomposting	$y=0.02x^2+0.02x+1.58$ ($R^2=0.95$)	$y=0.04x^2+0.02x+1.58$ ($R^2=0.95$)	$y=0.02x^2+0.02x+1.58$ ($R^2=0.95$)
	Pond slurry	$y=-0.01x^2+0.47x+1.06$ ($R^2=0.93$)	$y=-0.01x^2+0.45x+1.06$ ($R^2=0.93$)	$y=-0.03x^2+0.68x+1.06$ ($R^2=0.93$)
Organomineral	OMF	$y=-0.001x^2+115x+0.43$ ($R^2=0.72$)	$y=-0.001x^2+151x+0.43$ ($R^2=0.72$)	$y=-0.001x^2+142x+0.43$ ($R^2=0.72$)
Inorganic	Diammonium phosphate	$y=-0.0006x^2+0.01x+2.80$ ($R^2=0.97$)	$y=-0.00009x^2+0.005x+2.80$ ($R^2=0.97$)	NA
	Urea	$y=0.00003x^2-0.01x+3.12$	NA	NA
	CMC(N.P.K.)	$y=-0.0005x^2+0.016x+3.14$ ($R^2=0.91$)	$y=-0.001x^2+0.023x+3.14$ ($R^2=0.91$)	$y=-0.0009x^2+0.021x+3.14$ ($R^2=0.91$)

Table 6. ANOVA significance levels (p-values) for various growth parameters

	Brinjal			**Cluster beans**		
Response	**Fertilizer**	**Concentration**	**Fertilizer: Concentration**	**Fertilizer**	**Concentration**	**Fertilizer: Concentration**
Shoot length	>0.001	>0.001	>0.001	>0.001	>0.001	>0.001
Root length	>0.001	>0.001	>0.001	>0.001	>0.001	>0.001
Fresh Weight	>0.001	>0.001	>0.001	>0.001	>0.001	>0.001
Dry weight	>0.001	>0.001	>0.001	>0.001	>0.001	>0.001
Germination	>0.001	>0.001	>0.001	>0.001	>0.001	>0.001

fertilizer concentrations beyond the available range and optimise fertilizer doses to get the expected growth and development (Monika *et al.,* 2022). Tables 2, 3, 4 and 5 represent the regression equations that show the relationship between the N, P, and K content of different fertilizers and their effect on shoot and root elongation of cluster bean and brinjal. It would help to determine whether the observed effects were statistically significant or not. The brinjal R^2 value for shoot and root elongation ranges from 0.71 to 0.99 (Tables 2 and 3). R^2 is higher when there is a linear relationship between the predictor and response variable. For example, shoot and root elongation increased with increasing concentration of fertilizers in the case of organic fertilizers while decreasing in the case of inorganic fertilizers, and both show higher R^2 values. In the case of cluster bean, similar trends were observed as in the case of brinjal. R^2 value ranged from 0.57 to 0.95, in shoot elongation (Table 4) and 0.72 to 0.97 in root elongation (Table 5). Studies suggested that organic fertilizers like poultry, farmyard manure, and vermicompost promote soil microbiota, which is essential for nutrient recycling and soil fertility, leading to better growth parameters and higher yield (Joshi *et al.,* 2015; Wani *et al.,* 2017). Adekiya *et al.* (2022) reported that using poultry manure increases sorghum yield and positively influences the soil properties. Organomineral fertilizers provide a variety of macro, micronutrients and organic matter, making them preferable to other fertilizers. Organomineral fertilizers enhance plant growth, including yield and absorption of nutrients, compared to using manure or inorganic fertilizers separately (Ojo *et al.,* 2014 and Smith *et al., 2020*). Moreover, many workers suggested that organomineral fertilizers derived from animal manure and mineral fertilizers have a higher potential to increase plant height, no of leaves, seed weight, fruit size, etc, in various crops like maize, tomato, corn, etc. (Sakurada *et al.,*2016 and Ayeni and Ezeh, 2017). It has been found that urea and other water-soluble fertilizers were highly beneficial for the vegetative growth of soybeans and enhanced plant height, no. of branches, fruit, other physiological and biochemical parameters (Kılınçoğlu *et al.,* 2023). Continuous use of inorganic fertilizers without organic fractions leads to several changes in soil properties like high acidification, leaching, and depletion of energy for soil microbes, ultimately affecting crop health (Menšík *et al.,* 2018). Applying organic fertilizers blended with inorganic fertilizers maintains sustainable growth and yield without compromising soil health.

Conclusion

The present study on the effects of various organic, inorganic, and organomineral fertilizers on brinjal and cluster bean showed that organomineral fertilizer at a concentration of 220 mg/L was the most effective, offering the highest growth parameters like RGR, shoot length, root length, fresh weight and dry weight.This study suggested that increasing the dose of fertilizers for higher yield can also inhibit seed germination and growth. Additionally, organomineral fertilizers seemed good for plants because they serve both organic and inorganic fractions. These fertilizers ensured a steady supply of nutrients to plants and better survival of crop species because of their slow-releasing organic and fast-releasing inorganic components.

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Conflict of interest

The authors declare that they have no conflict of interest.

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