EFFECT OF INTEGRATED USE OF ORGANIC AND INORGANIC FERTILIZERS ON GRAIN YIELD AND NUTRIENT UPTAKE OF MAIZE

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ABSTRACT

Continuous cropping and traditional farming often lead to micronutrient deficiencies in Sindh's agricultural soils, which pose significant challenges to agricultural productivity. This deficiency can result in decreased nutrient uptake by crops, leading to stunted growth, reduced yields, and lower nutritional content in their produce. The field trials were laid out in Randomize Complete Block Design (RCBD) (factorial) with 3 replicates. The study tested five treatments of Chemical Fertilizer (CF) CF: FYM ratios (%) of 0:100, 25:75, 50:50, 75:25, and 100:0. Using the best CF: FYM ratio of 75:25 and not watering enough led to plant heights of 192.41 and 177.55 cm, 18.43 and 14.29 green leaves per plant, 15.19 and 14.01 internodes per stalk, 6.12 and 5.50 cm stem girth, 96.46 and 90.22 cm ear heights, 20.18 and 18.36 cm ear lengths, 252.17 and 226.95 g ear weights, and 13.84 and 12.61 grain rows. cob^{-1}, 474.28 & 404 grains cob^{-1}, 61.58 & 55.12 g grain weight. The kernel weight for cob-1 was 0.297 & 0.248 g, the seed index was 296.89 & 248.15 g, the biological yield was 10626 & 9166 kg ha^{-1}, the grain yield was 3653.3 & 2872.7 kg ha-1, the harvest index was 34.38 & 31.34%, the plant N was 2.56 & 2.37%, the plant P was 0.135 & 0.125%, the plant K was 1.483 & 1.423%, the plant Fe was 118.9 & 114.14%, and the plant Zn was 16.55 & 15.89%, respectively. The CF: FYM ratio of 75:25% was more preferable than sole CF or sole NPK due to economically optimum crop productivity and regular soil amendment for organic matter during cropping.

Keywords: Maize, CF, FYM ratio, grain yield, plant nutrients content

INTRODUCTION

Maize (*Zea mays* L.) is a versatile cereal crop with widespread cultivation for various purposes. It finds application in both human and animal nutrition, as well as in industrial processes and as a source of fuel. Global research, including studies by Derby *et al*. (2005) and Pavlik *et al*. (2019), has highlighted maize as a primary choice for food, feed, fodder, fuel, and industrial production. In 2023, global maize production witnessed significant fluctuations and challenges influenced by various factors, including climate conditions, pest outbreaks, and market dynamics. Despite these challenges, maize production remained a critical component of the world's agricultural landscape. Several countries, such as the United States, Brazil, China, and Argentina, continued to be major contributors to the global maize output (FAO, 2022). In Pakistan, maize plays a pivotal role as a source of food and fodder, contributing 6.4% to the country's total grain production, as reported by Abdullah *et al*. (2007) and Mahmood *et al*. (2017). Yang *et al*. (2018) indicate that the importance of maize in both animal feed and grain production has attracted substantial global attention. Numerous factors, including soil fertility, imbalanced nutrition, disrupted soil properties, the cultivation of specific varieties, and weed infestations, present challenges to global maize production. Various strategies are employed to improve and maximize maize yields, with the strategic use of fertilizers recognized as a critical factor affecting crop productivity. Among the essential nutrients utilized, nitrogen (N), phosphorus (P), and potassium (K) are of particular importance for vigorous plant growth. Numerous studies have extensively documented their functions, which include roles in processes like photosynthesis, enzyme activity, protein and carbohydrate synthesis, and strengthening the plant's resistance to pests and diseases (Tisdale *et al*., 1985). Agricultural soils, however, are increasingly deficient in these vital nutrients required for achieving higher crop yields. Achieving a well-balanced nutritional profile is imperative for cultivating healthy and profitable maize crop, involving not only N, P, and K but also a range of micronutrients. Imbalances among these elements can result in deficiencies or toxicities, underscoring the significance of maintaining the correct nutrient equilibrium (Miller and Gilbert, 2006). Given that plants necessitate significant amounts of N, P, K, sulfur, magnesium, and calcium, we classify these as macronutrients and refer to the remaining elements as micronutrients (Miller and Gilbert, 2010).

MATERIALS AND METHODS

At the Students' Experimental Farm, Department of Agronomy, Sindh Agriculture University Tandojam, we investigated the treatment effect on the growth, yield, and grain quality of the maize variety "Pak-Afgoi" during the

Rabi (winter season) of years 2020-21 and 2021-22, under the agro ecological conditions of Tandojam (25°26'N latitude and 68°32 E longitude). The experiments were laid out in RCBD (factorial) with 3 replicates. The experiment included five integrated levels of organic fertilizer (FYM) and inorganic fertilizer (NPK) at various ratios.

Experimental design = factors Randomized Complete Block Split Plot Design
Net plot size: 5 m × 6 m = 30 m².
Variety: Pak-Afgoi (Hybrid)
Sowing method: drilling
Treatments = 05
Fertilizer Integration:
T_1 = 100% FYM ha^{-1}
T_2 = 25% chemical fertilizers (CF) + 75% FYM ha^{-1}
T_3 = 50% CF + 50% FYMha-1.
$_{T4}$ = 75% CF + 25% FYM ha^{-1}.
T_5 = -100% CFha-1

Statistical analysis

The collected data were subjected to statistical analysis using Statistix 8.1 computer software. The two-way ANOVA was applied to examine the significance of the treatments and their interactions' effects on maize parameters. The LSD test was applied to compare treatments' means considering the significance of the treatments' effect (Steel *et al*., 1997).

RESULTS

Plant height (cm)

These results illustrate the impact of combinations of chemical fertilizers (CF) and farmyard manure (FYM) on the height of maize plants, measured at harvesting time. Table 1 showed that each treatment had a significant effect on plant height ($p < 0.05$). The results showed that using 100% FYM made the plants grow the shortest, with an average height of 167.56 cm. A mix of 25% CF and 75% FYM made the plants grow a little taller, to 170.93 cm. An equal distribution of 50% CF and 50% FYM led to a further increase in plant height to 179.95 cm, while increasing the CF to 75% and maintaining 25% FYM resulted in the tallest plants, with an average height of 184.98 cm. Using 100% CF resulted in a plant height of 177.00 cm, which was higher than using 100% FYM but not as tall as the combination with 75% CF and 25% FYM. Chemical fertilizers and farmyard manure, when used in a balanced combination, can enhance maize plant height, with a higher proportion of chemical fertilizers achieving the greatest height.

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The number of green leaves

These results illustrate the impact of combinations of chemical fertilizers (CF) and farmyard manure (FYM) on the number of green leaves, measured at harvesting time. Table 1 shows that each treatment had a significant effect on plant height ($p < 0.05$). Using 100% FYM resulted in the shortest number of green leaves, with an average of 15.47 cm. The number of green leaves was slightly higher when 25% CF and 75% FYM were mixed, at 170.93 cm. An equal distribution of 50% CF and 50% FYM led to a further increase in the number of green leaves to 179.95 cm, while increasing the CF to 75% and maintaining 25% FYM resulted in the tallest number of green leaves, with an average of 184.98 cm. Using 100% CF resulted in 177.00 cm of green leaves, which was higher than using 100% FYM but not as tall as the combination with 75% CF and 25% FYM. A balanced combination of chemical fertilizers and farmyard manure can increase the number of green leaves in maize, with a higher proportion of chemical fertilizers and farmyard manure yielding the highest number of green leaves.

Number of green leaves

The effect of fertilizer treatment consisted of ratio of chemical fertilizers (CF) and farmyard manure (FYM) as well as on green leaves plant^{-1} of maize was significant ($p < 0.05$). The Table 1. Further exhibited that the highest leaf count was observed in plants treated with 100% chemical fertilizer (F_5), averaging 16.45 green leaves plant^{-1}. On the other hand, plants treated with 100% farmyard manure (F_1) had the lowest leaf count, with an average of 15.47 green leaves plant^{-1}. Treatments involving various combinations of chemical fertilizer and farmyard manure (F2, F3, F4) showed intermediate leaf counts. Among fertilizer treatments, F_4, which consists of 75% chemical fertilizer (CF) and 25% farmyard manure (FYM), is recommended as the optimum combination due to the nonsignificant difference in the number of green leaves plant^{-1} when compared to F_3 (50% CF + 50% FYM) and F5 (100% CF) treatments. F_4 resulted in an average leaf count of 16.36 green leaves plant^{-1}, which was very close to the leaf counts achieved in F_3 (16.39) and F_5 (16.45) treatments. This similarity in leaf count suggests that F_4 can provide similar benefits in terms of leaf development while potentially reducing the reliance on pure chemical fertilizer (F_5), which could be more cost-effective and environmentally sustainable.

Table 1. Plant height (cm) and number of green leaves plant^{-1} of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	**Treatments**	**Plant height (cm)**	**Number of green leaves plant^{-1}**
A. Fertilizer treatments			
F_1	100% Farmyard manure (FYM)	167.56 d	15.47 c
F_2	25% Chemical fertilizers (CF) + 75% FYM	170.93 cd	16.00 b
F_3	50% CF + 50% FYM	179.95 ab	16.39 a
F_4	75% CF + 25% FYM	184.98 a	16.36 a
F_5	100% CF	177.00 bc	16.45 a
P-Value		*0.0015*	*0.0000*
S.E.±		*3.7467*	*0.1332*
LSD 0.05		*7.8716*	*0.2886*

Number of internodes stalk^{-1}

It was found that fertilizer treatments (CF/FYM Ratio) had a significant effect on the number of internodes stalk^{-1} in maize (p<0.05), but the interaction between fertilizer treatments and irrigation regimes was not significant (p>0.05). Table 2 shows that among the fertilizer treatments, F4, consisting of 75% chemical fertilizer (CF) and 25% farmyard manure (FYM), produced the highest number of internodes, with an average of 14.60 internodes stalk-1. F3, which used 50% CF and 50% FYM, closely followed this treatment with an average of 14.54 internodes stalk-1. However, F2, with 25% CF and 75% FYM, had the lowest number of internodes, averaging 13.74 internodes stalk^{-1}. F1, involving 100% FYM, had an intermediate number of internodes, averaging 13.27 internodes stalk-1, while F5, consisting of 100% CF, had an average of 14.00 internodes stalk^{-1}.

Stem girth (cm)

The fertilizer treatments (CF/FYM ratio), as well as their interaction, had a significant effect on the stem girth of maize (p < 0.05). Table 2 further indicated that in fertilizer treatments, F1, involving 100% farmyard manure (FYM), resulted in the maximum stem girth, averaging 6.25 cm. F2, which used 25% chemical fertilizers (CF) and 75% FYM, followed this treatment with an average stem girth of 6.09 cm. F3, which used a 50% CF and 50% FYM mixture, had an intermediate stem girth of 5.97 cm. Meanwhile, F4, which used 75% CF and 25% FYM, produced plants with a slightly lower stem girth of 5.81 cm. F5, using 100% CF, had the lowest stem girth, averaging 5.46 cm.

Table 2. Number of internodes stalk^{-1} and stem girth (cm) of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	**Treatments**	**Number of internodes stalk^{-1}**	**Stem girth (cm)**
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	13.27 c	6.25 a
F2	25% Chemical fertilizers (CF) + 75% FYM	13.74 bc	6.09 b
F3	50% CF + 50% FYM	14.54 a	5.97 c
F4	75% CF + 25% FYM	14.60 a	5.81 d
F5	100% CF	14.00 ab	5.46 e
P-Value		0.0029	0.0000
S.E.±		0.3218	0.0080
LSD 0.05		0.6760	0.0169

Ear height (cm)

Table 3. The fertilizer treatments, including chemical fertilizers (CF) and farmyard manure (FYM) ratio, as well as their interaction, had a significant impact on the ear height of maize ($p < 0.05$). In fertilizer treatments, F1 (100% FYM) resulted in the tallest ear height (96.97 cm), followed by F2 (25% CF and 75% FYM) with an average ear height of 95.75 cm, while F3 (50% CF and 50% FYM mixture) had a slightly smaller ear height of 94.42 cm. The ear height of F4, which contained 75% CF and 25% FYM, declined to 93.33 cm, while F5, which used 100% CF, had the lowest ear height at 92.61 cm.

Ear length (cm)

The effect of fertilizer management (including different proportions of chemical fertilizers [CF] and farmyard manure [FYM]). As well, their interactive effect on the ear length of maize was statistically significant ($p < 0.05$). Among the fertilizer regimes, F4 (75% CF and 25% FYM) maximized the length of maize ears (19.27 cm), closely followed by F3, which used 50% CF and 50% FYM, resulting in an average ear length of 18.88 cm. Similarly, F5, which contained 100% CF, also showed relatively longer ears (18.77 cm), while F2, which included 25% CF and 75% FYM, had slightly shorter ears (18.54 cm), and F1, which included 100% FYM, had the shortest ears (18.41 cm) in maize (Table 3).

Table 3. Ear height (cm) and ear length (cm) of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	**Treatments**	**Ear height (cm)**	**Ear length (cm)**
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	96.97 a	18.41 e
F2	25% Chemical fertilizers (CF) + 75% FYM	95.75 b	18.54 d
F3	50% CF + 50% FYM	94.42 c	18.88 b
F4	75% CF + 25% FYM	93.33 d	19.27 a
F5	100% CF	92.61 e	18.77 c
P-Value		0.0000	0.0000
S.E.±		0.2649	0.0053
LSD 0.05		0.5566	0.0112

Ear weight (g)

The fertilizer treatments comprised of varying ratios of chemical fertilizers [CF] and farmyard manure [FYM]. As well as their interactions had a significant ($p < 0.05$) impact on ear weight of maize. The results showing the effect of different fertilizer treatments on ear weight (table 4) exhibited that F4 (75% CF and 25% FYM) resulted in the maximum ear weight, averaging 239.56 g, which was closely followed by F3, where 50% CF and 50% FYM were used, with an average ear weight of 225.38 g. Similarly, F2 (25% CF and 75% FYM) exhibited an average ear weight of 221.39 g, and F5 (100% CF) showed an average ear weight of 224.13 g, while the F1 (100% FYM) had the lowest ear weight, averaging 219.79 g.

Number of grain rows: Cob^{-1}

The cob^{-1} ratio in maize is a crucial factor that influences crop yield. The data (Table 4) revealed a significant ($p < 0.05$) influence of varying ratios of chemical fertilizers [CF] and farmyard manure [FYM]. The effect of different fertilizer treatments showed that among treatments, F4, which consists of 75% CF and 25% FYM, resulted in the highest number of grain rows, averaging 13.22 rows cob-1. This treatment was followed by F5, containing 100% CF, which had an average of 12.53 rows cob-1. The treatment F3 (50% CF and 50% FYM mixture) exhibited satisfactory number of grain rows (12.52 rows cob-1), while treatment F2 (25% CF and 75% FYM) had a slightly lower number of grain rows (12.30 rows cob-1). However, the treatment F1, consisting of 100% FYM, had the lowest number of grain rows (12.21 rows, cob^{-1}).

Table 4. Ear weight (g) and number of grain rows cob^{-1}of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Ear weight (g)	Number of grain rows cob-1
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	219.79 e	12.21 c
F2	25% Chemical fertilizers (CF) + 75% FYM	221.39 d	12.30 c
F3	50% CF + 50% FYM	225.38 b	12.52 b
F4	75% CF + 25% FYM	239.56 a	13.22 a
F5	100% CF	224.13 c	12.53 b
P-Value		0.0000	0.0000
S.E.±		0.2510	0.0751
LSD 0.05		0.5273	0.1578

Number of grains: Cob^{-1}

The results on the number of grains cob^{-1} in maize (Table .5) revealed a significant ($p < 0.05$) impact of the variable ratio of chemical fertilizers [CF] and farmyard manure [FYM]. It is obvious that F4, comprised of 75% CF and 25% FYM, showed highest efficacy, resulting in an impressive average of 439.14 grains cob^{-1}, and this treatment stood as most successful in terms of grain production. F5, consisting of 100% CF, also showed positive effectiveness, with an average of 413.06 grains cob^{-1}, while F3 (50% CF and 50% FYM blend) and F2 (25% CF and 75% FYM) produced a commendable average of 415.37 and 408.01 grains cob^{-1}, respectively. However, F1 (100% FYM) showed a somewhat lower efficacy, yielding an average of 405.07 grains cob^{-1}.

Weight of grains: Cob^{-1} (g)

The weight of grain cob^{-1} (Table 5) was significantly ($p < 0.05$) influenced by a change in the ratio of chemical fertilizers [CF] and farmyard manure [FYM]. The study of fertilizer regimes showed that F7, which had 75% CF and 25% FYM, increased the average weight of grains (58.35 g) cob^{-1} the most. This made it the best fertilizer regime for increasing grain weight cob^{-1} in maize. Similarly, F3, involving a 50% CF and 50% FYM, exhibited an average 56.20 g weight of grains cob^{-1}, while F5 (100% CF) produced an average grain weight of 54.59 g cob^{-1}. However, F2 (25% CF and 75% FYM) yielded an average of 53.65 g grains weight cob^{-1}, while F1 (100% FYM) resulted in the least average grain weight of 53.42 g cob^{-1}.

Kernel weight (g)

The kernel weight of maize was obtained and given in Table 6, and there was a significant ($p < 0.05$) effect of fertilizer regimes (CF = chemical fertilizers, FYM = farmyard manure ratio). The highest kernel weight was found with fertilizer treatment F4, which was a mix of 75% CF and 25% FYM. It was 0.273 g. The next highest kernel weights were found with F3, which was a mix of 50% CF and 50% FYM, and the lowest were with F1, which was

100% FYM. The treatment F2, which contained 25% CF and 75% FYM, resulted in a kernel weight of 0.254 g, while F5 (100% CF) displayed a lower kernel weight of 0.250 g.

Table 5. Number of grains cob^{-1} and grain weight cob^{-1} (g) of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Number of grains cob-1	Grain weight cob^{-1} (g)
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	405.07 e	53.42 d
F2	25% Chemical fertilizers (CF) + 75% FYM	408.01 d	53.65 d
F3	50% CF + 50% FYM	415.37 b	56.20 b
F4	75% CF + 25% FYM	439.14 a	58.35 a
F5	100% CF	413.06 c	54.59 c
P-Value		0.0000	0.0000
S.E.±		0.1112	0.2121
LSD 0.05		0.2337	0.4455

Seed index (1000 seed weight) (g)

The results in table 6 revealed that the seed index value of maize was significantly ($p < 0.05$) influenced by treatments based on fertilizer regimes (CF/FYM ratio). The experiment with different fertilizer regimes showed that F4, which is made up of 75% CF and 25% FYM, had the highest seed index (272.52 g) for every 1000 seeds. This treatment showed that it could increase seed weight. F3, comprising a balanced 50% CF and 50% FYM blend, also exhibited a relatively higher seed index (259.78 g), while F1 (100% FYM) resulted in an average seed index of 255.17 g. However, F2 (25% CF and 75% FYM) resulted in an average seed index of 253.98 g, and F5 (100% CF) resulted in the lowest seed index (250 g).

Table 6. Kernel weight (g) and seed index (g) of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Kernel weight (g)	Seed index(g)
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	0.256 bc	255.17 c
F2	25% Chemical fertilizers (CF) + 75% FYM	0.254 c	253.98 c
F3	50% CF + 50% FYM	0.260 b	259.78 b
F4	75% CF + 25% FYM	0.273 a	272.52 a
F5	100% CF	0.250 c	250.00 d
P-Value		0.0000	0.0000
S.E.±		0.0029	1.0644
LSD 0.05		0.0061	2.2362

Biological yield (kg ha^{-1})

The results in table 7 indicate that the biological yield of maize was significantly ($p < 0.05$) affected by chemical fertilizers (CF) and farmyard manure (FYM) ratio. The biological yield of maize increases gradually from the lowest to the highest value of chemical fertilizer (CF) to the farmyard manure (FYM) ratio, with the highest yield observed at 75% CF + 25% FYM (9896.1 kg), followed closely by 100% CF (9719.4 kg), 50% CF + 50% FYM (9658.3 kg), 25% CF + 75% FYM (9204.7 kg), and FYM 100% (9066.1 kg). This trend suggests that while both CF and FYM contribute to maize growth, a higher proportion of CF results in increased biological yield.

Grain yield (kg ha⁻¹)

The results in table 7 indicate that the grain yield of maize was significantly ($p < 0.05$) affected by chemical fertilizers (CF) and farmyard manure (The ratios of different chemical fertilizers (CF) and farmyard manure (FYM) on grain yield showed dissimilar trends across different treatment combinations. mbinations. The highest grain yield was observed at the 75% CF + 25% FYM ratio (3263.0 kg), followed by 50% CF + 50% FYM (3065.9 kg) and 100% CF (3003.7 kg), indicating the superiority of CF-based treatments in promoting maize grain yield. However, 100% FYM records the lowest grain yield (2943.2 kg), indicating that organic fertilizer alone may not provide sufficient nutrients for maximum yield. The moderate combination of 25% CF + 75% FYM exhibits a slightly higher yield (2992.9 kg) than 100% CF, indicating the importance of a balanced combination of CF and FYM for optimal grain production in maize.

Table 7. Biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}) of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Biological yield (kg ha-1)	Grain yield (kg ha-1)
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	9066.1 e	2943.2 e
F2	25% Chemical fertilizers (CF) + 75% FYM	9204.7 d	2992.9 d
F3	50% CF + 50% FYM	9658.3 c	3065.9 b
F4	75% CF + 25% FYM	9896.1 a	3263.0 a
F5	100% CF	9719.4 b	3003.7 c
P-Value		0.0000	0.0000
S.E.±		20.744	0.6819
LSD 0.05		43.581	1.4326

Harvest index (%)

Table 8 exhibited that the harvest of maize was significantly ($p < 0.05$) influenced by the change in ratio of chemical fertilizers (CF) and farmyard manure (FYM). The effect of different ratios of chemical fertilizer (CF) and farmyard manure (FYM) on the harvest index (%) of maize reveals varying trends across different combinations. The highest harvest index is observed at the 75% CF + 25% FYM ratio (32.86%), followed by 25% CF + 75% FYM (32.46%) and 100% FYM (32.42%), indicating the beneficial effect of a balanced combination of CF and FYM on the proportion of grain yield to total biomass. However, 100% CF (30.89%) records the lowest harvest index, suggesting that excessive use of chemical fertilizer may lead to lower efficiency in grain production compared to organic inputs alone or in combination with CF. The average mix of 50% CF and 50% FYM has a slightly lower harvest index (31.67%) than the best mix of 75% CF and 25% FYM. This suggests that while CF helps with overall biomass, using more FYM may improve maize grain yield efficiency.

Leaf N content (%)

Table.8 further showed that the leaf N content in maize was significantly ($p < 0.05$) affected by the ratio of chemical fertilizers (CF)/farmyard manure (FYM). The amount of nitrogen (N) in maize leaves changes when different amounts of chemical fertilizer (CF) and farmyard manure (FYM) are mixed. The trends are different for each mix. The highest leaf N content is observed at the 75% CF + 25% FYM ratio and 100% CF, both resulting in a leaf N content of 2.47%. This indicates that higher proportions of CF contribute to increased nitrogen levels in maize leaves. Conversely, 100% FYM records the lowest leaf N content (2.27%), indicating that organic fertilizer alone may not provide sufficient nitrogen for optimal leaf development. The moderate mix of 25% CF and 75% FYM has a slightly higher nitrogen content in the leaves (2.34%) than 100% FYM. This shows how important it is for maize to have a balanced mix of CF and FYM for nitrogen uptake. Additionally, the 50% CF + 50% FYM ratio demonstrates an intermediate leaf N content of 2.40%, highlighting the synergistic effect of combining chemical and organic fertilizers for nitrogen management in maize.

Table 8. Harvest index (%) and plant N content (%)of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Harvest index (%)	Plant N content (%)
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	32.42 b	2.27 d
F2	25% Chemical fertilizers (CF) + 75% FYM	32.46 b	2.34 c
F3	50% CF + 50% FYM	31.67 c	2.40 b
F4	75% CF + 25% FYM	32.86 a	2.47 a
F5	100% CF	30.89 d	2.47 a
P-Value		0.0000	0.0000
S.E.±		0.0676	0.0035
LSD 0.05		0.1420	0.0074

Leaf P content (%)

Table 9 exhibited that the leaf P in maize was significantly ($p < 0.05$) associated with the ratio of chemical fertilizers (CF)/farmyard manure (FYM). There was a gradual increase in leaf P concentration with higher proportions of CF. The highest leaf P content was observed at both the 75% CF + 25% FYM and 100% CF ratios, resulting in a leaf P content of 0.130%. This suggests that CF-based treatments contribute to increased phosphorus levels in maize leaves. Conversely, 100% FYM recorded the lowest leaf P content (0.120%), suggesting that organic fertilizer alone may not provide sufficient phosphorus for optimal leaf development. The moderate mix of 25% CF and 75% FYM has a slightly higher leaf P content (0.123%) than 100% FYM. This shows how important it is for maize to have a balanced mix of CF and FYM for phosphorus uptake. Moreover, a 50% CF + 50% FYM ratio demonstrates an intermediate leaf P content of 0.126%.

Leaf K content (%)

Table 9 further indicated that leaf K concentration in maize was significantly ($p < 0.05$) influenced by the ratio of chemical fertilizers (CF) to farmyard manure (FYM). The effect of different CF:FYM ratios on leaf potassium (K) content (%) of maize plants demonstrates varied responses across treatments. The 75% CF + 25% FYM ratio yields the highest leaf K content, with a value of 1.453%. This suggests that a higher proportion of CF contributes to increased potassium levels in maize leaves. Similarly, 50% CF + 50% FYM (1.391%) and 100% FYM (1.398%) recorded the lowest leaf K content, suggesting that a balanced combination of CF and FYM or organic fertilizer alone may not provide sufficient potassium for optimal leaf development. The moderate combination of 25% CF plus 75% FYM exhibits a slightly lower leaf K content (1.394%) than the highest ratio, suggesting that a higher proportion of FYM may have a slight negative effect on potassium uptake, while 100% CF demonstrates an intermediate leaf K content of 1.444%

Table 9. Plants P content (%) and plant K content (%)of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Plant P content (%)	Plant K content (%)
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	0.120 d	1.398 c
F2	25% Chemical fertilizers (CF) + 75% FYM	0.123 c	1.394 d
F3	50% CF + 50% FYM	0.126 b	1.391 e
F4	75% CF + 25% FYM	0.130 a	1.453 a
F5	100% CF	0.130 a	1.444 b
	P-Value	0.0000	0.0000
	S.E.±	0.0009	0.0011
	LSD 0.05	0.0018	0.0021

Leaf Fe content (%)

The data in table 4.1.10 showed that leaf Fe concentration in maize plants was significantly ($p < 0.05$) inclined due to the CF:FYM ratio. The influence of different CF:FYM ratios on leaf iron (Fe) content (%) of maize plants shows a clear trend of decreasing Fe concentration with higher proportions of chemical fertilizer (CF) in the ratio. The highest leaf Fe content was observed with 100% FYM (134.91%), indicating that organic fertilizer alone contributes to higher iron levels in maize leaves. However, 100% CF recorded the lowest leaf Fe content (111.40%), indicating that CF-based treatments may not provide sufficient iron for optimal leaf development. The moderate mix of 25% CF and 75% FYM has a slightly higher leaf Fe content (128.52%) than higher CF ratios, which shows that FYM helps plants take in iron. Additionally, the 50% CF + 50% FYM and 75% CF + 25% FYM ratios demonstrate intermediate leaf Fe contents of 118.22% and 116.52%, respectively.

Leaf Zn content (%)

The results (Table 4.1.10) further revealed that leaf Zn in maize plants was significantly ($p < 0.05$) inclined due to the CF:FYM ratio. The amount of zinc (Zn) in the leaves of maize plants changes when different amounts of chemical fertilizer (CF) and farmyard manure (FYM) are added. The amount of Zn goes down gradually as the CF portion of the ratio goes up. The highest leaf Zn content was observed with 100% FYM (18.19%), indicating that organic fertilizer alone contributes to higher zinc levels in maize leaves. Conversely, 100% CF (15.02%) recorded the lowest leaf Zn content, indicating that only CF-based treatments may not provide sufficient zinc for optimal leaf development. The moderate mix of 25% CF and 75% FYM has a slightly higher leaf Zn content (18.08%) than higher CF ratios, which shows that FYM helps plants take in zinc. Additionally, the 50% CF + 50% FYM and 75% CF + 25% FYM ratios demonstrate intermediate leaf Zn contents of 16.61% and 16.22%, respectively, suggesting a balanced combination of CF and FYM may optimize zinc levels in maize leaves.

Table 10. Plant Fe content (%) and plant Zn content (%)of maize under the influence of integrated use of FYM and CFs at different ratio.

Tr#	Treatments	Plant Fe Content (%)	Plant Zn Content (%)
A. Fertilizer treatments			
F1	100% Farmyard manure (FYM)	134.91 a	18.19 a
F2	25% Chemical fertilizers (CF) + 75% FYM	128.62 b	18.08 b
F3	50% CF + 50% FYM	118.22 c	16.61 c
F4	75% CF + 25% FY	116.52 d	16.22 d
F5	100% CF	111.40 e	15.02 e
	P-Value	0.0000	0.0000
	S.E.±	0.3684	0.0034
	LSD 0.05	0.7741	0.0071

DISCUSSION

The farming communities in Pakistan are largely unaware of the importance of micronutrients for crop production, and they have generally observed a deficiency in major micronutrients in their agricultural soils, resulting in lower potential crop yields. Particularly, the agricultural soils of Sindh province often suffer from micronutrient deficiencies, posing significant challenges to agricultural productivity. This deficiency can result in decreased nutrient uptake by crops, leading to stunted growth, reduced yields, and lower nutritional content in their produce. Current study of the best result CF: FYM ratio of 75:25 and not watering enough led to plant heights of 192.41 and 177.55 cm, 18.43 and 14.29 green leaves per plant, 15.19 and 14.01 internodes per stalk, 6.12 and 5.50 cm stem girth, 96.46 and 90.22 cm ear heights, 20.18 and 18.36 cm ear lengths, 252.17 and 226.95 g ear weights, and 13.84 and 12.61 grain rows. cob-1, 474.28 & 404 grains cob-1, 61.58 & 55.12 g grain weight. The kernel weight for cob-1 was 0.297 & 0.248 g, the seed index was 296.89 & 248.15 g, the biological yield was 10626 & 9166 kg ha-1, the grain yield was 3653.3 & 2872.7 kg ha-1, the harvest index was 34.38 & 31.34%, the plant N was 2.56

&2.37%, the plant P was 0.135 & 0.125%, the plant K was 1.483 & 1.423%, the plant Fe was 118.9 & 114.14%, and the plant Zn was 16.55 & 15.89%. The CF: FYM ratio is 75:25. Raising the pH of the soil and overusing chemical fertilizers decreased soil fertility, even though their application helped improve nutritional deficiencies. % was more preferred than sole CF or sole NPK due to the economically optimum crop productivity and the specific soil amendment for organic matter during cropping. The findings of the study are in agreement with many past workers who have reported their macronutrients in different parts of the world. According to Agridea (2007), deficiencies in these elements result in reduced development, and all the micro and macronutrients needed for this crop's increased output must be present in higher amounts. By increasing the pH of the soil, overuse of chemical fertilizers decreased soil fertility, even when their application helped improve nutritional deficiencies. The FYM is one of the most commonly used organic manures, providing organic carbon, nitrogen, phosphorus, potassium, and various micronutrients (Bolan *et al*., 2007). In addition to chemical fertilizers, the FYM fosters vigorous maize growth and higher yields (Chivenge *et al*., 2009); it also enhances soil structure, water-holding capacity, and action exchange capacity. These soil enhancements create favorable conditions for root development and nutrient uptake by maize (Powlson *et al*., 2011). The application of FYM enriched maize grains with essential nutrients, including protein, minerals, and vitamins. This enhanced the nutritional quality of maize as both human food and animal feed (Rehman *et al*., 2018). The incorporation of FYM enhanced soil microbial diversity, activity, and overall soil health (Chen *et al*., 2018). FYM has a significant positive impact on maize yield and grain quality. They supply essential nutrients, improve soil fertility, enhance disease resistance, and promote sustainable agricultural practices. Moreover, organic manures contributed to the production of nutritionally superior maize grains and reduced the environmental footprint of maize cultivation. Kolawole (2014) reports that the timing of fertilizer application can significantly impact crop production, with the flowering approach being the most crucial period for fertilizer application. Boateng *et al*. (2009) showed FYM was still a useful fertilizer and could be used as an excellent alternate to chemical fertilizer. The FYM at 4 t ha^{-1} produced a yield of maize grain of 2.07 t ha^{-1}, which was statistically comparable to the yields of the chemical fertilizer rate (2.29 t ha^{-1}) and 6 t ha-1 (2.60 t ha^{-1}). Mahmood *et al*. (2017) tested the integrated use of organic and inorganic nutrients against maize production. Applying fertilizer together with organic manures significantly improved maize growth and yield, whereas applying inorganic fertilizers either alone or in combination with organic manures increased the soil's total organic C and total N, P, and K levels. However, the use of organic fertilizer led to a decrease in soil pH and mass density, which had a negative correlation with grain production. Combining different types of organic manures made applying nitrogen more effective, helped recover micro- and macronutrients, made it easier for plants to dissolve and absorb P, and raised the availability of K. All of these things led to better maize growth and yield. Applying both organic and inorganic fertilizers together is considered an effective method to enhance plant development, nutrient recovery, and final production; alternatively, larger N and P treatment rates are required to improve maize output (Mubeen *et al*., 2013). Negassa *et al*. (2001) and Shisanya *et al*. (2009) reported improved growth and yield-related characteristics in maize. The combined application of organic and inorganic nutrient sources improved the integration and cooperation between nutrient release and plant recovery, which in turn led to improved crop growth and yield (Huang *et al*., 2010). The organic manure application along with inorganic fertilizers also induced alterations in the physiochemical properties of soil. The addition of organic manures, regardless of their nature, abridged soil pH (Mahmood *et al*., 2017). According to Chen *et al*. (2010) and Shahzad *et al*. (2015), the addition of organic manures significantly increased soil organic carbon (SOC), which in turn had a major impact on soil microorganisms, nutrient availability, and absorption, potentially affecting the C:N ratio. According to Lawogbomo *et al*. (2017), who identified the impact of various FYM on maize growth and yield, applying FYM significantly ($P < 0.5$) increased plant height, leaf area index, number of leaves, total dry matter, ear length, and grain yield in comparison to the control. In comparison to the lowest ear and grain yields (7.05 and 3.66 t ha^{-1}, respectively) from the control, the plots treated with rabbit dung showed the greatest biological yield (11.61 t ha^{-1}) and grain yield (5.77 t ha^{-1}). Singh *et al*. (2019) reported that FYM fostered beneficial soil microorganisms, contributing to nutrient cycling and decomposition of organic matter. This resulted in improved nutrient availability to maize plants. The combination of NPK and FYM balanced nutrient supply, as maize had varying nutrient demands at different growth stages. The integration of FYM with NPK fertilizers proved essential for achieving high maize yields sustainably. This approach ensures a balanced nutrient supply, enhances soil health, improves crop resilience, and contributes to the long-term sustainability of agriculture. For farmers striving to maximize maize production while maintaining soil fertility and environmental responsibility, the utilization of FYM in nutrient management practices is not only advantageous but necessary. Worku *et al*. (2017) observed a significant increase in maize yields with the application of NPK, and demonstrated that FYM, abundant in organic matter and essential nutrients, improves soil fertility and maize yields. In 2018, Mondal *et al*. looked at how different NPK/FYM ratios affected the properties of the soil and the yield of maize. They found that organic matter from FYM improved soil fertility and nutrient availability, which led to a higher yield of maize when combined with the right NPK ratios.

Kumar *et al*. (2019) investigated the residual effects of different NPK/FYM ratios on subsequent maize crops and revealed that the choice of NPK/FYM ratio in previous seasons had a lasting impact on soil fertility and maize yield in subsequent years, highlighting the importance of long-term nutrient management planning.

Conclusions

Therefore, applying five treatments of CF: FYM ratios (%) of 0:100, 25:75, 50:50, 75:25, and 100:0. The CF: FYM ratio of 75:25% was more preferable than sole CF or sole NPK due to economically optimum crop productivity and regular soil amendment for organic matter during cropping.

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