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Influence of different nutrient management practices on maize growth and productivity in an acid hill soil of Himachal Pradesh

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Abstract

The present investigation was conducted during 2022 at Palampur, India in a continuing experiment from 2020, consisting of eleven treatments with three replications in a randomized block design with soybean grown as an intercrop in natural farming plots only. The results revealed that maize grain equivalent yield (MGEY), maize stover equivalent yield (MSEY), maize growth parameters *viz*. plant height at maturity, number of cobs plant^{-1}, number of seeds cob^{-1} and 1000-seed weight were highest under 100% NPK + FYM followed by 100% NPK + lime, while low performance was recorded under natural farming system using products from buffalo. Among non-chemical treatments, organic farming and natural farming (SPNF) showed better results followed by NFS-Crossbred cow. The integrated treatments of organic and natural farming were superior over their sole applications which underscore the importance of combining organic and inorganic sources.

Key words: Maize, Growth attributes, Crop yield, Organic farming, Natural farming, Integrated nutrient management

Maize (*Zea mays* L.) is pivotal in global agriculture, serving as a key food source, fodder, and industrial input (Murdia *et al*., 2016) and is one of the most important cereal crops of Himachal Pradesh (Thakur *et al*., 2019). As a C_4 plant with an extensive leaf area, maize efficiently captures and utilizes solar energy, enabling higher dry matter accumulation compared to most other cereals. Its unique photosynthetic pathway enhances productivity, allowing it to achieve a high biological and grain yield within relatively short growth period. Its adaptability across diverse climates makes it a global staple food (Tanotra *et al*., 2021). In India, maize holds a crucial position in the nation's food security, following only rice and wheat in importance. Its resilience, high yield potential, and rich nutritional profile have cemented its role in bolstering the agricultural economy. In the hilly terrains of Himachal Pradesh, maize emerges as the principal *kharif* crop, forming the dietary mainstay for a significant portion of the population (Choudhary *et al*., 2013). Fertilizers have been the backbone of increased food grain production. There has been stern concern about long term adverse effect of incessant and indiscriminate use of inorganic fertilizers to augment soil fertility and crop productivity as it often leads to negative effect on the complex system of biogeochemical cycles (Sharma *et al*., 2014 & 2016). However, an imbalanced nutrient supply, particularly in cereal-based systems, has gradually drained the soil's nutrient reserves, threatening long-term productivity (Katoch *et al*., 2024). In the acidic hill soils of Himachal Pradesh, the prolonged and excessive use of chemical fertilizers has led to several detrimental consequences. Over-reliance on these fertilizers exacerbates soil acidity, disrupts nutrient balance, and deteriorates soil health (Chaudhari *et al*., 2020). This over-reliance not only diminishes microbial activity and nutrient availability but also contributes to environmental issues such as water pollution from runoff and leaching. Innovative nutrient management strategies are essential to address these challenges and sustain maize productivity.

Organic farming practices, which emphasize the use of natural manures like farmyard manure (FYM), vermicompost, vermiwash, and biofertilizers, offer a more sustainable approach to enhancing soil fertility (Siddique *et al*., 2014). Organic farming not only improves soil structure and water retention but also

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fosters a thriving community of beneficial soil microorganisms. However, the nutrient demands of high-yielding maize varieties, especially in nutrient-depleted acidic soils, often surpass what organic farming alone can supply. Amidst this backdrop, Subhash Palekar's Natural Farming (SPNF) has gained prominence as a holistic alternative to both chemical and organic farming. In SPNF, locally sourced materials is used with a particular focus on cow-based products like *jeevamrit, beejamrit,* and *ghanjeevamrit*, which are derived from cow dung, urine, and other natural ingredients. These formulations are believed to enrich the soil microbiome and enhance nutrient cycling (Dev *et al*., 2022). The role of desi (indigenous) cow is particularly highlighted in SPNF, but many farmers in the region primarily rear crossbred cows or buffaloes (Vishvamitera *et al*., 2024). Therefore, it is important to assess the effectiveness of dung and urine from these animals compared to that from desi cows in creating the formulations used in natural farming. Additionally, combining a small amount of chemical fertilizers at sowing to support early crop growth with the use of excreta from crossbred cattle or buffaloes in natural farming practices should be explored to develop a practical and effective management approach.

Another promising approach to managing acidic soils is the integration of lime with chemical fertilizers. Liming improves microbiological activities in acidic soils and promote mineralization of organic materials (Sharma and Sharma, 2016) besides, it can mitigate soil acidity, fostering a more balanced nutrient environment that promotes better crop growth and yield (Agyin-Birikorang *et al*., 2022). In this context, Integrated Nutrient Management (INM) emerges as a key strategy. INM seeks to maintain high crop productivity while minimizing environmental impact by combining the judicious use of chemical fertilizers with organic and biological inputs (Wu and Ma, 2015). For maize cultivation in the challenging acidic soils of Himachal Pradesh, INM practices are particularly pertinent, addressing the dual needs of sustainable soil management and enhanced crop productivity. This study, therefore, investigates the influence of various nutrient management practices including chemical fertilizers, organic farming, SPNF, lime application, and INM on maize growth and productivity in the acidic hill soils of Himachal Pradesh. Through this integrative approach, we aim to improve the potential of maize cultivation in this region, ensuring both productivity and sustainability

Materials and Methods

The present study on maize was conducted in 2022 at the research farm of the Department of Agronomy at Bhadhiarkhar, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (Himachal Pradesh) in an ongoing experiment since 2020, situated at an altitude of 1290 meters above sea level, with coordinates 32°6´N latitude and 76°3´E longitude. The research area falls within the mid-hills sub-humid agro-climatic zone, characterized by a wet temperate climate. The site received a significant total rainfall of 1857.4 mm during the growing season, primarily concentrated between July and September, which accounts for nearly 80% of the annual precipitation. Throughout the study period, weekly temperature fluctuations were noted, with minimum temperatures ranged from 13.43°C to 21.84°C, and maximum temperatures varied between 24.21°C and 34.16°C. The site experienced diverse sunshine hours, spanning from as low as 1.64 hours to as high as 9.29 hours per week, while relative humidity levels fluctuated between 30.50 and 91.14%. The soil at the experimental location is identified as *Typic Hapludalf*; with a silty clay loam texture, providing a nuanced understanding of the environmental and edaphic conditions that influenced the maize crop during the study.

Experimental details: The experiment comprised of eleven treatments, each replicated three times, and arranged in a randomized block design (RBD). The treatments were 100% NPK (T_1), 100% NPK + FYM (Farmyard manure) (T_2), 100% NPK + lime (T_3), organic farming (T_4), natural farming system – SPNF (T_5), natural farming system using products from crossbred cow (T_6), natural farming system using products from buffalo (T_7), organic farming + 25% NPK (T_8), natural farming system – SPNF + 25% NPK (T_9), natural farming system using products from crossbred cow + 25% NPK (T_{10}), natural farming system using products from buffalo + 25% NPK (T_{11}).

The 100% NPK treatment (T_1) involved the application of 120 kg of nitrogen (N), 60 kg of phosphorus (P), and 40 kg of potassium (K) ha^{-1} for maize, supplied through urea, single super phosphate, and muriate of potash, respectively. A pre-sowing irrigation was provided, with subsequent water needs met by rainfall. In the 100% NPK + FYM treatment (T_2), FYM (on a dry weight basis) @ 10 tonnes ha^{-1} was incorporated at sowing time. Lime was applied at a rate of 1.8 tonnes ha^{-1} approximately four weeks before sowing in the 100% NPK + lime (T_3). Phosphorus and potassium were applied in full at sowing, while nitrogen was split, with half applied at sowing and the remaining half top-dressed in two equal portions during the knee-high and pre-tasseling stages. For the organic farming treatment (T_4), 60 kg of nitrogen ha^{-1} was provided through FYM, with an additional 60 kg of nitrogen ha^{-1} supplemented *via* vermicompost. Additionally, seeds were treated with biofertilizers (Azotobacter and PSB) before sowing and vermiwash was sprayed at a concentration of 10% every 15 days throughout the crop growth. In the natural farming treatments (T_5, T_6, and T_7), different formulations like *beejamrit*, *ghanjeevamrit*, and *jeevamrit* were prepared using the urine and excreta of desi cow, crossbred cow, and buffalo, respectively. Raised beds were created with 9-inch deep channels between them. Before sowing, seeds were treated with *beejamrit* for 30 minutes. *Ghanjeevamrit* at 250 kg ha^{-1} and sieved FYM at 250 kg ha^{-1} were applied during sowing. *Jeevamrit* was applied @ 500 liters ha^{-1} at sowing and sprayed at 10% concentration every 21 days throughout the crop's growth. Mulching with locally available organic residues was practiced, and natural farming-specific plant protection measures were applied as needed. Fermented buttermilk was sprayed at 12.5 liters ha^{-1} around 60 days after sowing and again at the grain filling stage. Maize was cultivated at a spacing of 60 cm between rows and 20 cm between plants. In natural farming plots, soybean was intercropped with maize in a 2:1 ratio.

The maize crop was manually harvested on October 12, 2022 and various growth parameters were recorded. To measure maize plant height at maturity (cm), five plants were randomly selected and tagged in each plot. The height was measured from the base to the tip of the tassel using a ruler, and the average height at harvest was calculated. At harvest, the number of cobs $plant^{-1}$ was determined by counting the cobs from the five tagged plants in each plot and averaging the results. For number of seeds cob^{-1}, five cobs were randomly chosen from each plot, and the seeds from each cob were counted to find the mean number of grains per cob. In case of 1000-seed weight (g), a composite sample of sun-dried grains was taken from each plot, and 100 grains were manually counted and weighed in grams. The weight of 1000 grains was then estimated by multiplying this weight by 10. Maize grain equivalent yield (MGEY) and maize stover equivalent yield (MSEY) was calculated by formulas given below-

MGEY = Yield of maize grain + [(Yield of soybean grain × Price of soybean grain) / Price of maize grain]

MSEY= Yield of maize stover + [(Yield of soybean straw × Price of soybean straw) / Price of maize stover]

The data were statistically analysed following Gomez and Gomez (1984) and the critical differences (CD) were assessed at $P \leq 0.05$.

Results and Discussions

Maize grain equivalent yield (MGEY)

To compare the productivity across various treatments, the maize grain equivalent yield (MGEY) was calculated using the prices of both maize and soybean grains. As depicted in figure 1, the treatment with 100% NPK + FYM (T_2) achieved the highest MGEY, followed by 100% NPK + lime (T_3). The integration of FYM and lime with 100% NPK resulted in MGEY values that were 5.14% and 13.12% higher, respectively, compared to the sole use of 100% NPK (T_1). The lowest MGEY was observed with the natural farming system using products from buffalo (T_7). Among the organic and natural farming treatments, the natural farming system – SPNF system (T_5) exhibited the highest MGEY, followed by natural farming system using crossbred cow (T_6). T_5 showed MGEY values that were 17.7%, 4.8%, and 12.7% higher than those of organic farming (T_4), natural farming system using products from crossbred cow (T_6), and natural farming system using products from buffalo (T_7), respectively. In the integrated organic and natural farming treatments, the highest MGEY was achieved with T_5 + 25% NPK (T_9), followed by T_6 + 25% NPK (T_{10}), T_7 + 25% NPK (T_{11}). The MGEY for T_5 + 25%

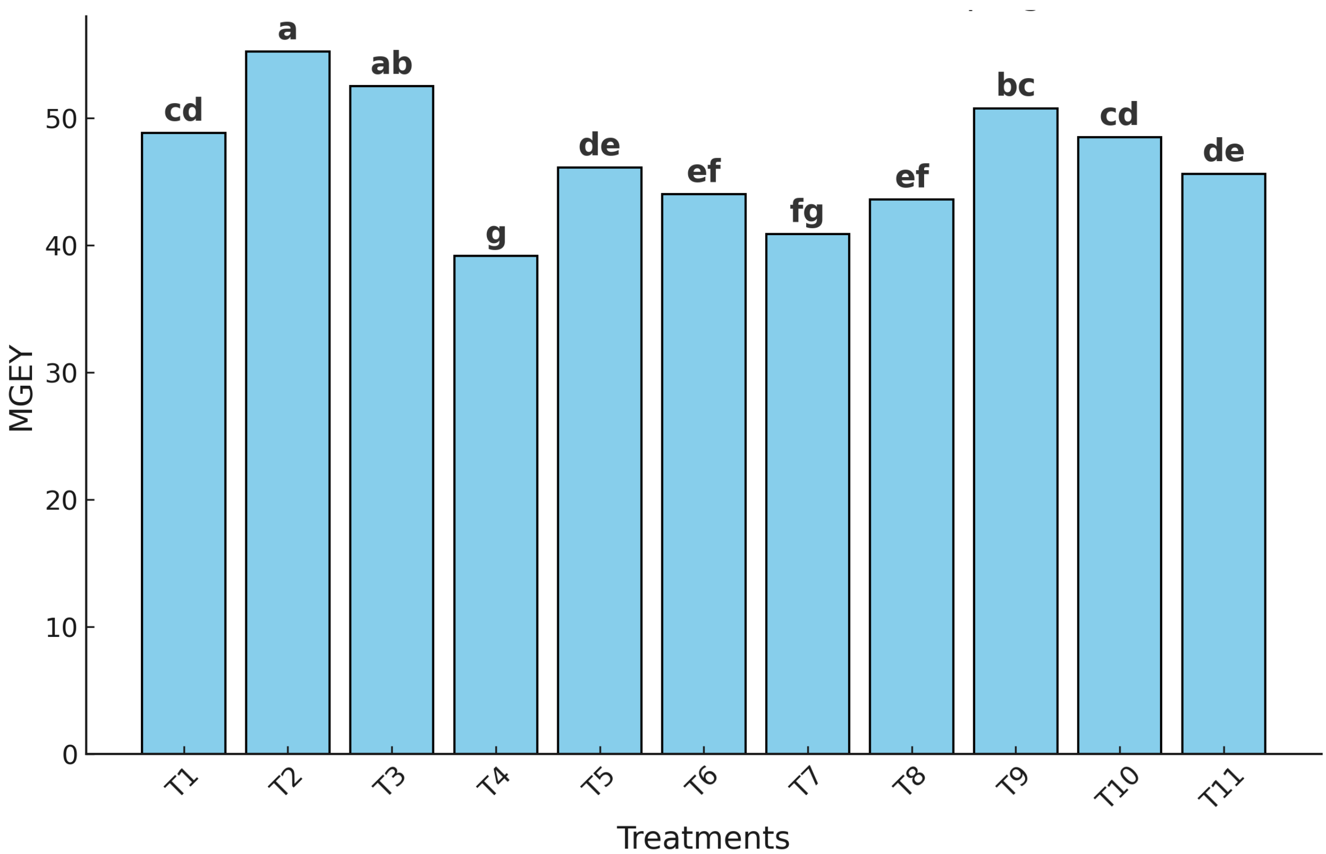

Figure 1: Maize grain equivalent yield (MGEY) (q ha^{-1}) under various nutrient management practices

NPK (T_9) was 16.4%, 4.7%, and 11.3% higher than that for T_4 + 25% NPK (T_8), T_6 + 25% NPK (T_{10}), and T_4 + 25% NPK (T_{11}), respectively. Also, all the integrated treatments were better than their sole application.

The superior performance of 100% NPK + FYM can be attributed to the balanced nutrient supply throughout the maize growth stages, enhancing grain yield of maize. This aligns with findings from Gourav *et al*. (2019). Conversely, the lower yield under the natural farming system using products from buffalo treatment (T_7) is likely due to the less NPK content in *beejamrit, jeevamrit,* and *ghanjeevamrit* prepared from buffalo products, as corroborated by Thakur et al. (2022) and Vishvamitera (2023). The increased MGEY in the natural farming system – SPNF system + 25% NPK treatment (T_9) compared to other integrated systems may be attributed to the higher soybean yield and nutrient availability, resulting from the better nutrient composition and microbial activity of the natural farming formulations using desi cow products, complemented by chemical fertilizers.

Maize stover equivalent yield (MSEY)

As presented in Figure 2, the highest maize stover equivalent yield (MSEY) was achieved with the 100% NPK + FYM treatment (T_2), surpassing 100% NPK + lime (T_3) by 3.13% and 100% NPK (T_1) by 11.86%. On the other hand, the lowest yield was observed under natural farming system using products from buffalo (T_7). Among the organic and natural farming treatments, organic farming (T_4) stood out, and was 8.6%, 11.0%, and 13.9% higher than natural farming system – SPNF system (T_5), natural farming system using products from crossbred cow (T_6), and natural farming system using products from buffalo (T_7), respectively. Similarly, T_4 + 25% NPK (T_8) outperformed T_5 + 25% NPK (T_9), T_6 + 25% NPK (T_{10}), and T_7 + 25% NPK (T_{11}) by 4.2%, 6.6%, and 11.1%, respectively. The superior performance of integrated treatments over their sole applications underscores the importance of combining organic and inorganic sources.

The remarkable MSEY under the 100% NPK + FYM treatment can be attributed to the complementary effects of organic and inorganic nutrients, ensuring a steady and balanced supply that drives robust maize growth. The inclusion of lime in the 100% NPK

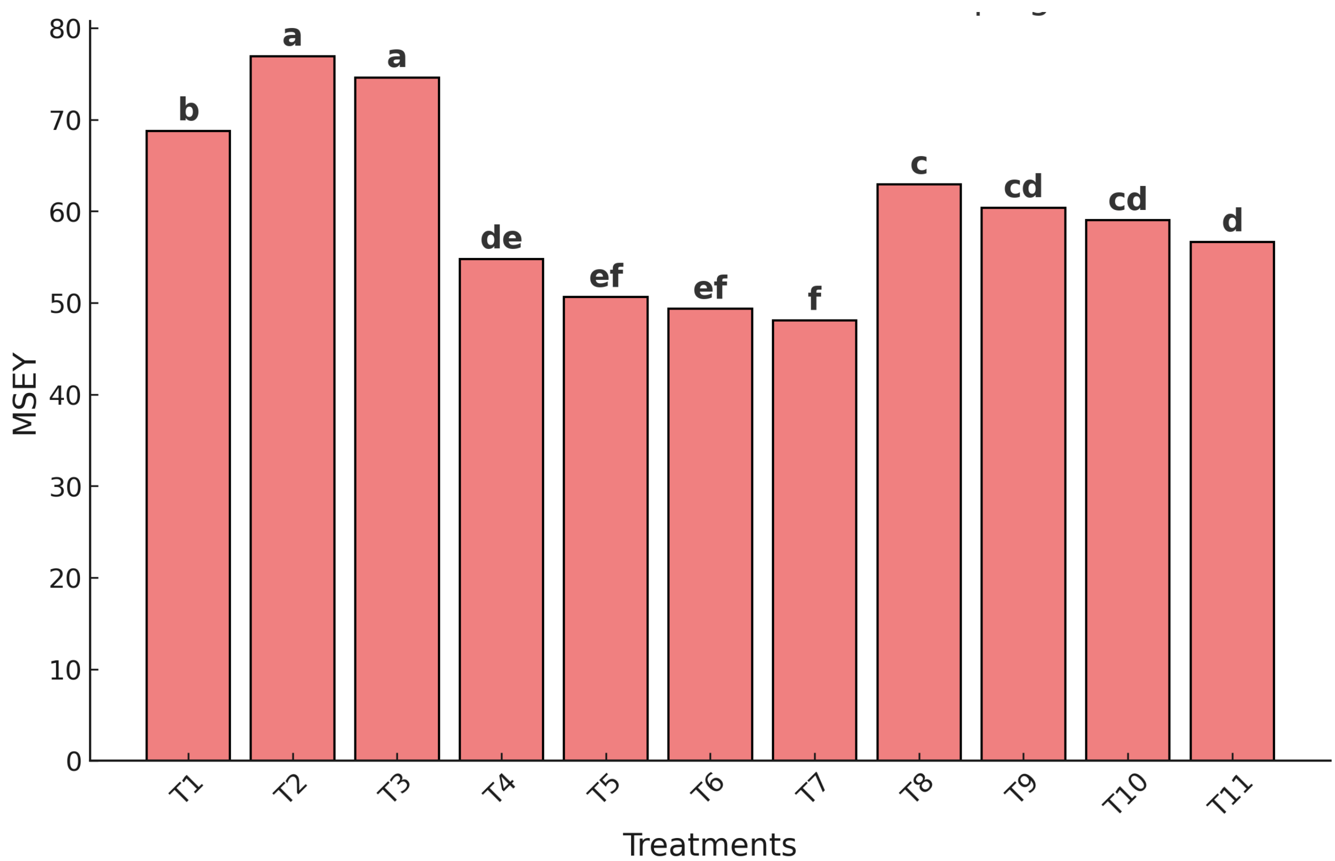

Figure 2: Maize stover equivalent yield (MSEY) (q ha^{-1}) under different nutrient management strategies

treatment likely enhanced soil pH and nutrient availability, further boosting crop performance. In contrast, the lowest yield under natural farming with buffalo inputs might be due to inconsistent nutrient availability, as traditional formulations may not fully meet the crop's needs. The superior results in organic farming over natural farming treatments highlight the more reliable nutrient provision from organic amendments, fostering better plant growth and yield. These findings align with those reported by Vishvamitera (2023).

Growth parameters

Plant height at maturity (cm):

The height of maize plants was significantly affected by the different treatments (Table 1). Among these, the tallest plants were observed in the 100% NPK + FYM (T_2), reaching 281.4 cm, followed by 100% NPK + lime (T_3) at 269.1 cm, which was statistically similar to 100% NPK (T_1). On the other hand, the shortest plants were recorded under natural farming system using products from buffalo (T_7). Within the organic and natural farming approaches, the tallest plants in the organic farming treatment (T_4) reached 251.1 cm, which was statistically comparable to the natural farming systems (T_5 and T_6) using products from desi and crossbred cows, respectively. In integrated approaches, the treatment T_4 + 25% NPK (T_8) was superior with a plant height of 260.1 cm which was statistically similar to T_5 + 25% NPK (T_9) and T_6 + 25% NPK (T_{10}). Notably, all the integrated treatments outperformed their respective non-integrated treatments, emphasizing the benefits of integrated nutrient management.

The tallest plants in the treatment comprising 100 per cent NPK + FYM might be attributed to the balanced nutrient supply of nutrients from FYM and chemical fertilizers, along with improved soil properties. This synergistic effect might have led to increased water and nutrient absorption, ultimately promoting plant growth. Lime application, when combined with inorganic fertilizers likely enhanced plant height due to the amelioration of soil acidity, creating a more favourable environment for nutrient availability and plant growth. Taller plants in organic farming compared to natural farming treatments might be due to the combined benefits from the application of

Table 1: Influence of different nutrient management practices on maize growth attributes

Treatments	Plant height at maturity (cm)	Number of cobs plant^{-1}	Number of seeds cob^{-1}	1000-seed weight (g)
T_1-100% NPK	263.1	1.1	478.7	250.9
T_2-100% NPK + FYM	281.4	1.5	511.1	254.2
T_3-100% NPK + lime as per requirement	269.1	1.3	497.5	252.8
T_4- Organic farming	251.1	1.1	447.7	247.3
T_5- Natural farming system – SPNF system	247.1	1.0	434.3	240.9
T_6- Natural farming system using products from crossbred cow	244.1	1.0	432.5	239.3
T_7- Natural farming system using products from buffalo	242.5	1.0	428.3	238.6
T_8- T_4 + 25% NPK	260.1	1.2	467.3	250.4
T_9- T_5 + 25% NPK	255.9	1.1	463.8	245.7
T_{10}- T_6 + 25% NPK	253.5	1.1	451.1	244.9
T_{11}- T_7 + 25% NPK	250.5	1.1	448.1	243.4
SEm(±)	2.5	0.1	5.5	0.9
LSD (P=0.05)	7.3	0.1	16.1	2.7

organic manures like FYM, vermicompost, vermiwash and seed treatment with biofertilizers, which likely sustained nutrient availability throughout the crop cycle, promoting better plant growth. The NFS–SPNF treatment produced taller plants as compared to NFS–Crossbred cow and NFS–Buffalo which may be linked to the higher microbial activity and nutrient content attributed to inputs dervied from the dung and urine of indigenous cows. Similar conclusions were drawn by Sharma *et al*. (2022) and Vishvamitera (2023).

Number of cobs plant^{-1}:

The different treatments significantly influenced the number of cobs plant^{-1}, as shown in Table 1. The 100% NPK + FYM treatment (T_2) outperformed all other treatments, recording the highest number of cobs plant^{-1}. This was closely followed by T_3 (100% NPK + lime) and T_8 (organic farming + 25% NPK). Among organic and natural farming practices, T_4 (organic farming) was superior, showing better results compared to T_5, T_6, and T_7. In integrated treatments, T_4 + 25% NPK (T_8) recorded better number of cobs plant^{-1}, surpassing T_9, T_{10}, and T_{11}. The highest number of cobs plant^{-1} in maize under the 100% NPK + FYM treatment can be linked to the balanced and enriched nutrient supply from combining chemical fertilizers with organic manure, which fosters robust plant growth and optimal cob development. Vishvamitera (2023) reported similar findings. The better performance of organic farming treatments over natural farming ones can be attributed to the more stable and balanced nutrient availability provided by organic amendments and a portion of chemical fertilizers, promoting consistent growth and cob formation. This observation aligns with the findings of Singh *et al*. (2019) and Noori *et al* (2023) in chilli-garden pea cropping system. On the other hand, natural farming treatments, which rely on traditional bio-formulations, might not deliver nutrients in sufficient amounts or at the right time, resulting in fewer number of cobs plant^{-1}. The lowest number of cobs per plant in natural farming treatments could be attributed to limited nutrient availability.

Number of seeds cob^{-1}:

Different treatments had a significant influence on the number of seeds cob^{-1} in maize (Table 1). The highest number of seeds cob^{-1} was observed in 100% NPK + FYM (T_2) i.e. 511.1, which was statistically similar to 100% NPK + lime (T_3) with 497.5. On the other hand, natural farming system using products from buffalo (T_7) recorded the lowest number of seeds cob^{-1} (428.3). Among the organic and natural farming treatments (T_4-T_7), organic farming (T_4) had the highest number of seeds cob^{-1} (447.7) which was statistically comparable to natural farming system – SPNF system (T_5) and natural farming system using products from crossbred cow (T6), and significantly superior to natural farming system using products from buffalo (T_7). In the integrated treatments (T_8-T_{11}), T_4 + 25% NPK (T_8) showed the highest number of seeds cob^{-1}

(467.3), statistically at par with T_5 + 25% NPK (T_9) and T_6 + 25% NPK (T_{10}), and significantly better than T_7 + 25% NPK (T_{11}). All the integrated treatments were superior to of their respective sole application. The superior number of seeds cob^{-1} in treatment with the integration of the recommended dose of fertilizers and FYM can be attributed to the continuous and balanced supply of nutrients as FYM enhances soil structure, boosts microbial activity, and provides a steady nutrient release, while NPK offers an immediate supply of essential nutrients, leading to improved seed formation. The inclusion of lime in the 100% NPK + lime treatment likely optimized soil pH, further improving nutrient uptake and seed development, as noted by Yigermal *et al*. (2019) and Vishvamitera (2023). The higher number of seeds cob^{-1} in organic farming treatments, comparable to natural farming using desi cow and crossbred cow products, might likely be due to the consistent and balanced nutrient supply from organic and natural farming inputs. In contrast, the lower seed production in natural farming using buffalo products may result from a less balanced nutrient supply. These observations align with findings by Sharma *et al.* (2022).

1000-seed weight:

The data pertaining to 1000-seed weight of maize, as shown in Table 1, reveals that different nutrient management practices have a significant impact on this trait. The highest 1000-seed weight was observed in treatment 100% NPK + FYM (T_2), with a weight of 254.2 g, followed by 100% NPK + lime (T_3), which recorded 252.8 g. In case of organic and natural farming practices, organic farming (T_4) stood out with the highest 1000-seed weight, surpassing T_5, T_6, and T_7 by 2.7%, 3.4%, and 3.7%, respectively. In the category of integrated treatments, T_4 + 25% NPK (T_8) recorded the highest 1000-seed weight, outperforming T_9, T_{10}, and T_{11} by 1.9%, 2.2%, and 2.9%, respectively. All integrated treatments proved to be significantly superior compared to their respective sole applications. The increase in 1000-seed weight with the combined application of the recommended dose of fertilizers along with FYM can be attributed to the enhanced nutrient use efficiency, promoting better plant growth and more effective grain filling in maize. These findings are consistent with those of Yigermal *et al*. (2019) and Vishvamitera (2023). The superior 1000-seed weight in organic farming practices compared to natural farming can be linked to the consistent and balanced nutrient supply from organic amendments, which foster optimal seed development. Conversely, natural farming, which relies on traditional formulations such as *jeevamrit, beejamrit,* and *ghanjeevamrit*, may not provide nutrients in sufficient quantities or at the optimal times to maximize seed weight. This leads to smaller seed sizes and a lower 1000-seed weight in natural farming treatments. These observations align with previous studies by Vishvamitera (2023). The NFS–Buffalo resulted in lowest 1000–seed weight which may be attributed to less nutrient availability and microbial activity in buffalo–derived formulations (*beejamrit, jeevamrit* and *ghanjeevamrit*), which might have led to less nutrient uptake at critical seed–filling stage.

Conclusions

The study underscores that integrating 100% NPK + FYM or lime significantly enhance the maize productivity as well as growth parameters in acid Alfisol soils of Himachal Pradesh. Organic farming and the natural faming system (NFS)-SPNF outperformed NFS-crossbred cow and NFS-buffalo treatments, however NFS-Crossbred cow closely followed the NFS-SPNF treatment in terms of maize growth and productivity. Furthermore, integrated approaches combining organic and natural sources with inorganic sources proved superior to their sole applications, highlighting the benefits of such combinations. These findings emphasize the significance of integrated nutrient management in achieving optimal maize yields and growth, highlighting the benefit of a balanced nutrient approach for sustainable agriculture in the region.

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