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INFLUENCE OF ORGANIC MANURES AND AMF ON THE GROWTH AND YIELD OF FIELD CROPS WITHIN A WILD POMEGRANATE AGROFORESTRY SYSTEM

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ABSTRACT

This study investigates the influence of organic manures and arbuscular mycorrhizal fungi (AMF) on the growth and yield of field crops within a wild pomegranate-based agroforestry system conducted over two years at Dr. Yashwanth Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The research evaluates the effects of farmyard manure, vermicompost, and AMF on tomatoes, soybeans, cauliflower, and garden pea cultivated under agroforestry and open field conditions. There is significant improvement in plant growth and yield across all crops when FYM vermicompost and AMF T_6 are used together, with the most noticeable improvements in agroforestry and open fields.

Keywords: Organic Manures Arbuscular Mycorrhizal Fungi (AMF), Agroforestry System, Open Field Conditions, Farmyard Manure (FYM), Vermicompost.

I. INTRODUCTION

Agroforestry is an ancient and sustainable agricultural practice that integrates trees with crops and livestock, enhancing ecological and economic benefits. It plays a crucial role in improving soil health, nutrient retention, erosion control, and carbon sequestration (Pankaj Thakur et al., 2018). Wild pomegranate (Punica granatum L.), native to Southwest Asia, thrives in the mid-hill regions of the Himalayas and is a valuable cash crop for rural communities (Pankaj Thakur et al., 2018). Vegetable cultivation, particularly in Himachal Pradesh, significantly contributes to the agricultural economy. Crops like tomato (Solanum lycopersicum L.), soybean (Glycine max), pea (Pisum sativum), and cauliflower (Brassica oleracea var. botrytis) play a vital role in ensuring food security and economic stability. Tomatoes are widely cultivated for their nutritional value, while soybean and pea enhance soil fertility through nitrogen fixation (Chhabra & Vishwakarma, 2019; Barakzai et al., 2020). Cauliflower, an essential vegetable in India, benefits from agroforestry-based cultivation, improving yield and sustainability (John Milton D, 2017). The excessive use of inorganic fertilizers has led to soil degradation, necessitating a shift toward organic amendments and biofertilizers. Organic manures such as farmyard manure (FYM) and vermicompost, along with biofertilizers like vesicular arbuscular mycorrhiza (VAM), enhance soil fertility, nutrient availability, and overall crop productivity (Nandapure et al., 2020; Abbas et al., 2019). Arbuscular Mycorrhizal Fungi (AMF) play a crucial role in improving phosphorus uptake, water absorption, and plant resistance to stresses, making them essential for sustainable agriculture (Xing L-J et al., 2022). Research indicates that AMF significantly influences plant growth, including flowering and fruit development, in various crops (Garmendia & Mangas, 2012; Bona et al., 2015; Dubsky et al., 2002). Thus, integrating organic nutrient management with agroforestry systems holds promise for sustainable crop production, ensuring improved soil health, enhanced yield, and environmental conservation.

II. METHODOLOGY

The experiment was conducted in an agri-horticultural system integrating wild pomegranate (Punica granatum L.) trees with field crops to assess the impact of farmyard manure (FYM), vermicompost, and arbuscular mycorrhizal fungi (AMF) (Glomus spp.) on crop growth and yield under two planting conditions: with and without wild pomegranate trees. Tomato (Solanum lycopersicum L., var. Himsona) and soybean (Glycine max, var. Harit Soya) were cultivated during Kharif, while cauliflower (Brassica oleracea var. botrytis L., var. Pusa Snowball K-1) and garden pea (Pisum sativum L., var. PB-89) were grown in Rabi using a factorial randomized block design (RBD) with three replications, total 42 experimental plots. The same plots were used for Rabi crops following Kharif cultivation. Seven manure treatments were applied: T1 (FYM @ 3 kg/plot), T2 (Vermicompost @ 5 kg/plot), T3 (AMF @ 4 g/plot), T4 (FYM @ 2 kg + AMF @ 2 g/plot), T5 (Vermicompost @ 3 kg + AMF @ 2 g/plot), T6 (FYM @ 2 kg + Vermicompost @ 3 kg + AMF @ 2 g/plot), and T7 (Control, no manure). Crop spacing varied (tomato and cauliflower: 60 cm × 45 cm; soybean and garden pea: 45 cm × 7.5 cm), with plot sizes of 4 m × 2 m. Growth parameters recorded for tomato included plant height, days to marketable maturity, number of fruits per plant, fruit dimensions, and yield per plant, plot, and hectare. Soybean parameters comprised plant height, branches per plant, pods per plant, grains per pod, fresh and dry weight of 100 seeds, and total yield per hectare. In cauliflower, days to curd maturity, curd weight per plant, curd yield per plot and hectare, and curd polar and equatorial diameters were observed, while garden pea parameters included plant height, pods per plant, pod length, grains per pod, and seed yield per hectare. This study aimed to evaluate the effectiveness of organic amendments on plant growth, and yield performance under Wild pomegranate-based Agroforestry system.

ANALYSIS

The data obtained from the present study were statistically analyzed following the procedure described by Gomez and Gomez (1984). The analysis of variance (ANOVA) was performed to determine the significance of differences among the treatment means. When significant differences were observed, the means were further compared using the critical difference (CD) at a 5% level of significance ($p \leq 0.05$).

III. RESULTS AND DISCUSSION

3. Growth parameters of Tomato (Solanum lycopersicum L.)

3.1 Plant Height (cm)

The tallest tomato plants were recorded in Treatment T6 (FYM + vermicompost + AMF) with an average height of 138.18 cm, whereas the shortest plants were observed in the control treatment (T7). This increase in plant height under T6 could be attributed to improved nutrient availability and microbial activity facilitated by organic amendments and AMF application. These findings align with earlier studies, such as those by Kumar et al. (2016), who reported a significant increase in chili pepper plant height with vermicompost and FYM application. Similarly, Kumar et al. (2021) found that a combination of organic manures and biofertilizers significantly increased plant height in okra.

3.2 Plant Spread (cm)

The maximum plant spread was recorded in T6 (56.37 cm), whereas the least spread was observed in T7. The enhanced plant spread in T6 can be attributed to better soil structure and nutrient uptake facilitated by organic amendments. Pal et al. (2019) reported similar results in cucumber, where the combination of vermicompost and poultry manure significantly increased plant spread compared to the control.

3.3 Days to First Flower

Tomato plants in T6 flowered earlier compared to those in T7, indicating that organic amendments and AMF positively influenced reproductive development. The enhancement in flowering could be linked to improved hormonal balance due to AMF interactions. Xing et al. (2022) reported that AMF advanced flowering by five days and prolonged the flowering period in snapdragon, highlighting the role of AMF in regulating plant hormonal balance.

3.4 Days to Marketable Maturity

Tomato plants in T6 reached marketable maturity significantly earlier than those in T7. This suggests that the integration of FYM, vermicompost, and AMF expedited fruit development. Sonkamble et al. (2022) observed similar effects in watermelon, where the shortest duration to edible maturity was achieved with vermicompost and biofertilizer applications.

3.5 Number of Fruits per Plant

The highest number of fruits per plant (9.25) was recorded in T6, while T7 had the lowest count. This increase in fruit production under T6 indicates the positive impact of organic amendments on reproductive growth. These findings are consistent with those of Pal et al. (2019), who found that the combination of vermicompost and poultry manure significantly increased fruit production in strawberries.

3.6 Average Fruit Weight (g)

The maximum average fruit weight was recorded in T6 (68.23 g), while the lowest fruit weight was observed in T7. The improved fruit weight in T6 is likely due to the availability of essential nutrients provided by the organic amendments. Ahamad et al. (2021) found that the combination of FYM and poultry manure significantly enhanced fruit weight in tomato.

3.7 Fruit Dimensions (cm)

The highest fruit length (5.61 cm) and width (4.46 cm) were recorded in T6, whereas T7 exhibited the smallest fruit size. This increase in fruit dimensions under T6 suggests improved cell expansion and carbohydrate accumulation. Soni et al. (2018) reported similar results in tomato, where the combination of vermicompost and poultry manure significantly improved fruit length and width compared to the control.

3.8 Fruit Yield per Plant (g)

The highest fruit yield per plant was recorded in T6 (556.57 g), whereas the lowest was observed in T7. The increased yield in T6 highlights the role of organic amendments in enhancing productivity. Sonkamble et al. (2022) reported that vermicompost and biofertilizer applications significantly increased fruit yield in watermelon, demonstrating the efficacy of organic nutrient management.

3.9 Fruit Yield per Hectare (q ha^{-1})

Under open field conditions (C2), the highest fruit yield per hectare was achieved in T6 (170.73 q ha^{-1}), whereas the lowest yield was recorded in T7 under agroforestry conditions (C1) (22.96 q ha^{-1}). The significant difference in yield under different conditions emphasizes the importance of nutrient management and growing conditions in optimizing productivity. These findings collectively demonstrate the superiority of integrated nutrient management (FYM + vermicompost + AMF) in enhancing tomato growth, fruit development, and overall yield.

IV. GROWTH AND YIELD PARAMETERS OF SOYBEAN (GLYCINE MAX L.)

4.1 Plant Height (cm)

Soybean plants exhibited significant variation in plant height across different treatments. The tallest plants (50.59 cm) were recorded in T6, while T7 had the shortest. The study highlights significant differences in plant height between agroforestry and sole cropping systems. Similar findings were reported by Suerman et al. (2022), who examined soybean intercropping under oil palm trees, where soybeans grown under shaded conditions exhibited taller growth due to etiolation. This phenomenon results from an imbalance in plant hormones, particularly increased auxin levels and reduced cytokinin levels (Mubarok et al., 2020; Nuraini et al., 2021; Rosniawaty et al., 2020), stimulating cell elongation and increasing plant height by over 25% (Widiastuti et al., 2004). Further, the present findings align with those of Rajya et al. (2015), who observed a significant impact of organic and inorganic fertilizer combinations on plant growth in tomatoes, with the tallest plants recorded in treatments enriched with farmyard manure and poultry manure, similar to the beneficial effects observed in soybean.

4.2 Days to First Flowering

Days to first flowering were delayed in T6 (58.73 days) compared to T7. These results align with Osman et al. (2011), who reported a significant delay in cowpea flowering in shaded agroforestry conditions compared to open-field cropping. A similar trend was observed in pearl millet, where spike emergence occurred earlier in plants located farther from tree trunks. These findings indicate that shading and nutrient availability influence flowering dynamics, as also reported by Akpo and Grouzis (1993).

4.3 Days Taken to Marketable Maturity of Pod

Soybean maturity was significantly influenced by treatments, with the earliest marketable maturity recorded in T3 (125.12 days), while T6 took the longest (129.63 days). Similar results were observed by Chouhan et al. (2018), who reported an extended harvest period for tomatoes grown under 50% shade-net conditions compared to open fields. The prolonged maturity period under agroforestry systems may be attributed to moderated environmental conditions, which enhance fruit development and stability.

4.4 Number of Pods per Plant

The highest number of pods per plant (31.69) was recorded in T6, while T7 had the least. The study indicates that the 2–3-year-old wild pomegranate-based agroforestry system created favorable growing conditions for soybean, improving soil moisture retention, reducing temperature fluctuations, and moderating evapotranspiration stress. These effects contributed to better plant health and increased pod production. Similar trends were reported by Singh and Yadav (2022), who observed significantly higher pod counts in soybean agroforestry systems compared to sole cropping.

The highest pod count was achieved with the application of farmyard manure, vermicompost, and arbuscular mycorrhizal fungi (T6), which enhanced soil fertility, microbial activity, and phosphorus uptake. These findings align with those of Karsh et al. (2024), who reported increased okra yield with integrated organic and inorganic fertilizers.

4.5 Number of Grains per Pod

The highest number of grains per pod was recorded in T6, although differences between treatments were not statistically significant. While agroforestry conditions (C1) consistently produced higher grain counts than open-field conditions (C2), variations were minimal. These results support findings by Schenck and Schroder (1994), who reported that AMF thrive at temperatures between 28°C and 34°C, with optimal vesicle expansion occurring at 35°C. Shaded intercropping environments, similar to those in soybean-oil palm systems, may provide favorable conditions for AMF, enhancing phosphorus availability and overall plant performance (Suerman et al., 2022). Similar findings were reported by Sultana et al. (2018), who observed that okra plants grown under reduced light conditions had significantly higher fruit production. Additionally, Masaku et al. (2018) and Mwangi et al. (2024) documented improved seed development in green gram under moderate shading.

4.6 Pod Length (cm)

Pod length was significantly influenced by treatments, with the maximum pod length (3.33 cm) observed in T6, whereas T7 produced the shortest pods. The combined application of organic manure and AMF enhanced plant growth more effectively than individual treatments, likely due to improved nutrient absorption (Hodge and Fitter, 2010). These findings align with those of Masaku et al. (2018), who reported longer pod lengths in green gram grown under shaded conditions compared to full sunlight. This suggests that moderate shading, as seen in agroforestry systems, may positively influence pod development.

4.7 100-Seed Fresh Weight (g)

The fresh and dry weight of 100 seeds was significantly higher in T6 compared to other treatments. Similar trends were observed in agroforestry studies, where integrated organic treatments improved grain weight through enhanced nutrient uptake. These findings confirm that combining organic manures and AMF enhances soybean productivity, particularly under agroforestry conditions, reinforcing the importance of tree-crop interactions in sustainable agricultural systems.

4.8 Pod Yield per Plot (kg)

The maximum pod yield per plot (4.51 kg) was observed in T6 under agroforestry conditions (C1), while T7 under open-field conditions (C2) recorded the lowest yield. These results suggest that agroforestry systems create microclimatic conditions that support higher yield potential, likely through enhanced soil fertility and moisture retention.

4.9 Pod Yield per Hectare (q ha^{-1})

The highest pod yield per hectare (31.69 q ha^{-1}) was observed in T6 under open conditions (C2), whereas T7 recorded the lowest (2.60 q ha^{-1}). The yield benefits of organic amendments, combined with AMF application, demonstrate the potential of sustainable nutrient management practices in soybean cultivation.

V. GROWTH AND YIELD PARAMETERS OF BRASSICA OLERACEA L.

5.1 Days Taken to Marketable Maturity

Cauliflower plants under different treatments showed significant differences in curd development. The longest days to marketable maturity were recorded in T6 under agroforestry conditions (C1) (183.96 days), whereas the earliest maturity was observed in T3 under open conditions (C2) (46.07 days). These findings align with those of Suherman and Edi Kurniawan (2016), who reported that different shade treatments significantly affect plant maturity and overall growth duration. Their study demonstrated that legume shade treatments extended the time to marketable maturity by 14 days, compared to 13 days for both monoculture and mixed shade treatments. Furthermore, the maturity period of fruit was significantly prolonged under legume shade conditions (261 days) compared to mixed shade (257 days) and monoculture shade (230 days). These results highlight the role of shading treatments in modifying plant growth dynamics, with legume shade potentially leading to extended growth periods and delayed maturity compared to other shading methods.

5.2 Net Curd Weight (g) per Plant

The maximum net curd weight per plant (688.46 g) was observed in T6 under C1, while the lowest curd weight was recorded in T7. Previous research supports these findings. Yasoda et al. (2018) investigated the impact of different shade levels on cauliflower growth and yield, focusing on mean curd weight. Their study found that curd initiation occurred earlier under 50% shade, while it was delayed at 25% shade, and completely inhibited at 75% shade. The highest mean curd weight (285 g) was recorded under 50% shade, significantly surpassing other treatments, whereas the lowest (160.03 g) was observed in open field conditions. The absence of curd formation at 75% shade was attributed to inadequate light intensity and reduced photosynthetic activity. These findings suggest that cauliflower performs optimally under moderate shading, likely due to improved environmental conditions, including optimal light intensity, temperature, and humidity, which collectively enhance photosynthesis and assimilate accumulation. Similar conclusions were reported in earlier studies by Swagatika et al. (2006) and Vethamoni and Natarajan (2008).

5.3 Net Curd Yield (kg) per Plot

Net curd weight per plot was highest in T6 under C2 (17.83 kg), while T7 under C1 had the least. The findings of Sonkamble et al. (2022) further support these observations, demonstrating that the combined application of vermicompost and biofertilizers significantly enhances fruit yield per vine compared to the use of farmyard manure alone. Specifically, the highest fruit yield (13.83 kg per vine) was achieved with the application of vermicompost at 13.5 t/ha in combination with Azotobacter and PSB, illustrating the superior efficacy of this treatment over farmyard manure alone, which resulted in a lower yield (8.90 kg per vine). These findings align with those of Ahmad et al. (2019) and Azarmi et al. (2009), who reported similar increases in yield following the application of organic and microbial treatments in cucumber.

5.4 Net Curd Weight (Quintal per ha)

The highest net curd weight per hectare (176.14 q ha^{-1}) was recorded in T6 under C2, whereas T7 under C1 had the lowest (40.72 q ha^{-1}). These findings align with those of Sonkamble et al. (2022), who reported that the application of vermicompost in combination with Azotobacter and PSB resulted in the highest fruit yield per hectare (87.68 tons). This underscores the synergistic effect of organic inputs and biofertilizers in enhancing crop productivity. In contrast, farmyard manure alone yielded 56.42 tons per hectare, suggesting that while it improves yield compared to no treatment, it is less effective than the integrated application of vermicompost and biofertilizers.

5.5 Polar Diameter (cm)

The polar diameter of curds was significantly influenced by treatments, with the largest curds observed in T6 under C1 (14.57 cm) and the smallest in T7 under C2. Vermicompost demonstrated superior efficacy in promoting cauliflower growth and yield compared to other organic manures. Notably, when combined with farmyard manure (FYM) and arbuscular mycorrhizal fungi (AMF), vermicompost exhibited a pronounced positive effect, enhancing both growth and yield more effectively than when applied alone. These findings align with those of Tyagi et al. (2022), who reported that the application of 50% vermicompost resulted in the maximum longitudinal head length of cauliflower (15.96 cm), whereas the control treatment, which excluded vermicompost, recorded a head length of 12.92 cm. This highlights the significant role of vermicompost in enhancing head development in cauliflower, likely due to its nutrient-rich composition and beneficial effects on soil health.

5.6 Equatorial Diameter (cm)

The equatorial diameter of curds was also significantly influenced by treatments, with the largest observed in T6 under C1 (18.08 cm) and the smallest in T7 under C2. These findings align with the results reported by Patil and Prasad (2020), who observed that a combination of 100% Farm Yard Manure (FYM) with NPK (150:120:120 kg ha^{-1}) significantly improved fruit weight and diameter compared to other fertiliser treatments. Similarly, Tyagi et al. (2022) demonstrated that applying 50% vermicompost resulted in a maximum equatorial curd length of 15.41 cm in cauliflower, compared to 11.85 cm under the control treatment. Collectively, these studies underscore the effectiveness of vermicompost and well-balanced fertilisation in improving both growth and yield parameters in crops.

VI. GROWTH AND YIELD PARAMETERS OF PEA (PISUM SATIVUM L.)

6.1. Plant Height (cm)

The results of the study indicated that the plant height of pea was significantly influenced by different planting conditions and organic amendments. Maximum plant heights of 44.40 cm and 48.19 cm were recorded under the agroforestry system (C1) compared to the open field condition (C2). The tallest plants (56.30 cm) were observed under the T4C1 combination, while the shortest (28.61 cm) occurred in T7C2. These findings align with previous research, such as Singh (2014), who reported that a combination of organic amendments significantly improved plant height in chili (Capsicum annuum). Similar results were observed by Pal et al. (2019) in onion, where treatments with vermicompost and poultry manure resulted in significantly taller plants.

6.2. Days to First Flower

Significant variation in days to first flower was recorded among different treatments. The agroforestry system (C1) supported earlier flowering, with recorded values of 62.44 and 62.56 days. Treatment T6 (FYM with vermicompost and AMF) resulted in the earliest flowering (62.50 and 61.40 days), while T7 (control) exhibited the longest duration. These findings align with those of Xing et al. (2022), who reported that AMF inoculation advanced flowering in snapdragons. Similarly, Garmendia and Mangas (2012) found that AMF promoted early flowering in ornamental plants, supporting the hypothesis that AMF improves endogenous hormone regulation for flowering.

6.3. Days to Marketable Maturity

Marketable maturity was significantly influenced by planting conditions and organic amendments. Under the agroforestry system, plants reached marketable maturity at 139.72 and 140.16 days. Treatment T3 exhibited the shortest maturity period (135.34 days), whereas T5 took the longest (147.61 days). These results align with Sonkamble et al. (2022), who found that organic amendments influenced the maturity period in watermelon, with vermicompost treatments leading to earlier maturity compared to control.

6.4. Number of Pods per Plant

The number of pods per plant was significantly affected by treatments and planting conditions. Maximum values of 9.30 and 9.66 pods per plant were recorded under agroforestry conditions. Treatment T6 resulted in the highest pod count (9.48 and 8.24 pods per plant), while T7 had the lowest. These findings corroborate those of Franczuk et al. (2023), who reported that AMF-inoculated plants yielded 0.8% to 5% more fruits than non-inoculated controls. Similar trends were reported by Faisal et al. (2010) and Román-García (2003), demonstrating the positive impact of AMF on fruit production.

6.5. Number of Grains per Pod

Significant variations in the number of grains per pod were observed across treatments. The maximum number of grains per pod (8.08) was recorded in T6C1, whereas the lowest was found in T7C2. Similar results were reported by Kumari et al. (2022), who found that pea plants treated with Rhizobium, PSB, and FYM had the highest grain count. The increased grain number was attributed to improved nutrient availability in the rhizosphere, facilitated by organic amendments and microbial inoculants.

6.6. Pod Length (cm)

Pod length was significantly affected by organic amendments and planting conditions. The longest pod length (8.58 cm) was recorded in T6C1, while the shortest (3.78 cm) was observed in T7. These findings align with research by Colla et al. (2014), who reported that mycorrhization with Glomus intraradices and Trichoderma atroviride increased fruit size in zucchini squash.

6.7. Fresh and Dry Weight of 100 Seeds (g)

Fresh and dry seed weights were higher under the agroforestry system (C1) compared to open field conditions (C2). The highest fresh weight (33.45 g) and dry weight (22.14 g) of 100 seeds were recorded in T6, while the lowest values were seen in T7. These results align with previous findings by Egbuchua et al. (2013) on ginger and Lepcha et al. (2019) on mango ginger, emphasizing the benefits of organic amendments on seed weight.

6.8. Pod Yield per Plot and per Hectare

The highest pod yield (11.61 kg/plot and 59.46 q ha^{-1}) was achieved in T6, while T7 recorded the lowest values (2.26 kg/plot and 2.16 q ha^{-1}). The open field condition (C2) generally resulted in higher pod yield than the agroforestry system (C1), with the maximum overall yield (63.76 q ha^{-1}) recorded in T6C2 and the lowest (1.78 q ha^{-1}) in T7C2. These findings align with studies by Mwangi et al. (2024) on green grams, where shading significantly influenced pod yield, and by Manohar Rao et al. (2005), who demonstrated the role of organic inputs in enhancing crop yield.

VII. CONCLUSION

The study revealed that organic manures, Arbuscular Mycorrhizal Fungi (AMF), and planting conditions had significant effects on the growth, flowering, maturity, and yield of pea, cauliflower, tomato, and soybean. The T6 treatment, which involved combined nutrient management, consistently resulted in the best performance across all parameters, while the control (T7) recorded the lowest values. Planting conditions played a crucial role: the agroforestry system generally supported better vegetative growth, improved nutrient uptake, and enhanced root development, whereas open field conditions promoted earlier maturity and higher marketable yield across all crops. For implementation, the integrated use of organic manures and AMF under optimized planting environments is highly recommended to maximize crop productivity.

Limitations

Despite the observed benefits, some limitations exist. The agroforestry system, while beneficial for growth parameters, often led to delayed maturity in crops like tomato and cauliflower, which may not be ideal for short-season farming. Additionally, the dependency on organic inputs and AMF requires careful management, as their effectiveness can vary based on soil conditions and climate. Future research should focus on optimizing the balance between vegetative growth and yield efficiency under different planting conditions.

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