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ORIGINAL ARTICLES

Performance of BSMRAU-developed vegetables under fruit tree-based agroforestry systems

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ABSTRACT

Many field crop lands are being transformed to fruit orchards in different locations of Bangladesh. There is an ample scope to cultivate intercrops in the orchards following scientific manner and proper technology including suitable varieties. In this study, mango and orange orchards were transformed to agroforestry system in Kotchandpur upazila under Jhenaidah district to investigate the performances of selected vegetable varieties (bottle gourd, stem amaranth, papaya, cauliflower, and country bean) developed by the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). Randomized complete block design was used to compare agroforestry (mango and orange orchards) and non-agroforestry (open field) treatments for identifying suitable tree-vegetable combinations. The results indicated that yields of the tested vegetables were higher in the non-agroforestry system (crop field without trees) compared to the agroforestry system. Yields of bottle gourd stem amaranth, cauliflower, and country bean in agroforestry systems decreased by 21, 7, 18, and 19%, respectively, compared to non-agroforestry system. On the contrary, yield reductions were 7.9, 15.7, 3.9 and 4.6% in mango-based agroforestry than orange-based agroforestry for bottle gourd, stem amaranth, cauliflower, and country bean, respectively. The findings suggested that although all the tested vegetables can be grown in agroforestry, but creeping type vegetables are less suitable. Despite the observed reduction in yields, the fruit tree-based agroforestry system demonstrated its potential as a viable alternative, offering to reduce crop failure risk to the farmers and optimizing land utilization. The order of the suitability of the tested vegetables are stem amaranth > cauliflower > country bean > bottle gourd in agroforestry systems.

Introduction

Weather fluctuations including temperature, extreme water dearth and flood-inducing precipitation in the next couple of years have been predicted to continue to impact in Bangladesh's agriculture (Shahid *et al.*, 2016; Rahman *et al.*, 2023). Therefore, perception regarding monocropping systems to provide high production with the aim of solving the food shortage problem under the changing scenario of climate has been dramatically changed. The development of agroforestry as a viable use of land has been

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especially emphasized in the developing countries like Bangladesh because of its numerous positive contributions (Das *et al.*, 2020; Das *et al.*, 2022). Moreover, agroforestry would be a feasible choice in this regard because it provides several benefits like food supply, employment and income generation, investment incentives and ecosystem services (Lasco *et al.*, 2014).

Agroforestry is an advanced farming method that vastly improves production per unit area per unit time through maximizing the usage of natural resources (FAO, 2008; Smith, 2010). It is a practical and inexpensive way of incorporating multiple forms of coordinating land usage through the combination of trees and crops on the same area, particularly for small-scale farmers. It is found to be one of the appropriate means of achieving sustainable production without causing any environmental destruction (Wilson and Lovell, 2016). It brings prosperity for millions of farmers contributing to extra profits, employment, improved food, and nutrition security (Beedy *et al.*, 2013; Estruch *et al.*, 2013; Waldron *et al.*, 2017). However, farmers understand that the initial stage of fruit orchards does not carry economic gains until the tree starts to produce fruit. The barren field of the orchard (up to five to six years) may be extensively utilized for planting seasonal crops (Gill and Bisaria, 1995; Lojka *et al.*, 2021). In this system, trees and agricultural crops are combined and they compete for growth resources, including light, water and nutrients (Swieter *et al.*, 2022). The resource sharing among component crops may results in complementary or competitive effects depending upon the nature of species involved in the system (Zhang *et al.*, 2015). Fruit tree-based agroforestry is the most suitable in terms of sustainability, overall production and tree-crop compatibility among the numerous common agroforestry systems (Miah *et al.*, 2018; Das *et al.*, 2022).

Mango (*Mangifera indica*), guava (*Psidium guajava*), jujube (*Ziziphus jujuba*), litchi (*Litchi chinensis)*, orange (*Citrus sinensis*) etc. are some of the fast-growing fruit trees that are well adapted for cultivation in farmers' fields due to tremendous nutritious benefits, improved demand in the market and affordable price (Rahman, 2021; Zaman and Marma, 2022; Abbas, 2023; Roy, 2023). The aforementioned fruit trees are profoundly grown throughout Bangladesh. The fruit species are predominantly planted in order to provide sufficient space within trees for growing short duration crops during the initial years. The vacant space between trees could be judiciously used for growing leguminous crops and vegetables. Even after the later stage of growth of fruit tree (six to ten years), partial shade loving vegetables and spices can also be grown. Although Bangladesh has achieved tremendous development in agricultural sectors particularly in grain production, still there are many challenges to make it sustainable. On the contrary, many agricultural lands are being converted to fruit orchards (Rana and Moniruzzaman, 2021). In general, farmers do not grow vegetables in the orchards, therefore the field crops and vegetables growing area is decreasing; though there are enough space in the orchards to grow crops.

So far, BSMRAU has released 77 varieties of different crops. But their potential production at the floor of orchards is not evaluated yet. In this study, BSMRAU released bottle gourd, stem amaranth, cauliflower, and country bean varieties were evaluated in agroforestry like mango and orange-based systems at Kotchandpur upazila under Jhenaidah district of Bangladesh.

Methodology

Study location, climate and soil

In order to conduct on-farm experiment, Kotchandpur upazila (Jhenaidah district) was visited extensively and experimental fields were selected (Fig. 1). The experiments were started from April 2021 to February 2022, covering Kharif-1 and Rabi seasons. The physiographic unit of the soil of this land is calcareous dark grey floodplain in texture representing the Agro-ecological zone of High Ganges River Floodplain (AEZ-11).

Establishment of orchard and treatment composition

A two-year old mango (var. *Amrapali*) and a three-year old orange (var. *Bari Kamala 2*) orchards were converted into agroforestry system where the selected vegetables were grown in between two rows of each tree species (Fig. 1). The mango and orange fields were selected for exploring the potentials of BSMRAU released vegetables as a component of fruit tree-based agroforestry systems. The row of mango orchard comprising of four trees with three separate blocks were considered as three replications. The distance between trees rows were maintained at 4m × 4m to provide enough space to grow associated crops. During Kharif-1, bottle gourd (*BU Hybrid Lau 1*; *PRIMA*) seedlings were planted (4m plant to plant and row to row distance) following a zigzag manner in both mango and orange orchard. Besides, seeds of stem amaranth (*BU Data 1*) were sown in line with 25 cm row to row distance in between the rows of mango and orange trees. After thinning, about 15 cm plant to plant distance was maintained. During Rabi season, seedlings of cauliflower (*BU Phulkopi 1*) were transplanted following 50 cm line and 25 cm plant spacing. Like bottle gourd, country bean (*IPSA Sheem 1*) seedings were planted between the trees. The experiment was conducted in a randomized complete block design (RCBD) and there were three treatments viz. mango orchard, orange orchard and open field (non-agroforestry) for each crop. The yield and yield contributing parameters were collected for each vegetables.

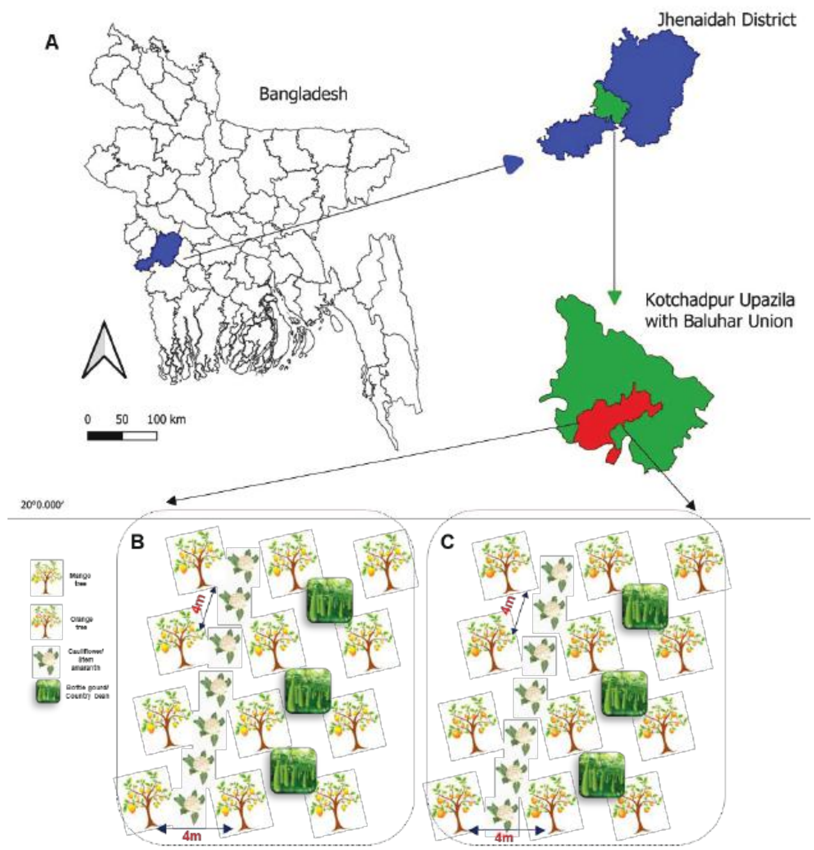

Fig. 1. Location of the experimental field at Kotchandpur Upazila, Jhenaidah district, Bangladesh (A); illustration of on-farm mango-based agroforestry system (B); and orange-based agroforestry system (C).

Field preparation, fertilizer application and intercultural operations

The land was initially prepared using a disk rotavator, followed by four passes of a tractor-drawn cultivator to ensure that the soil was well-prepared for planting vegetables in each season. During land preparation for bottle gourd, stem amaranth, cauliflower, and country bean, cow dung, vermicompost, DAP, and MoP fertilizers were applied based on the 2012 fertilizer recommendation guide (Hassan *et al.*, 2012). Irrigation was applied as needed using a flexible hose pipe to maintain adequate soil moisture. Weeding was done to minimize competition for resources between the crops and weeds. Additionally, strong bamboo stakes were provided to support the fruit-bearing capacity of bottle gourd and country bean plants. To control sucking insects and other pests, Dursban 20 EC at a rate of 2 ml per liter at 25-day intervals was applied. *Q-Phero* sex pheromone traps were used to reduce the infestation of fruit flies.

Statistical analysis

Data were analyzed using one-way analysis of variance (ANOVA). The treatments that showed significant differences were identified by assigning distinct alphabetical letters based on the least significant difference (LSD) test at a significance level of $P < 0.05$ using Statistix 10 software.

Results and Discussion

Performance of bottle gourd

The number of fruits per plant of bottle gourd varied significantly in agroforestry and non-agroforestry (open field) systems, where the highest number of fruits per plant was recorded in non-agroforestry system (Fig. 2) followed by sweet orange and mango-based agroforestry systems. There was no significant difference between two agroforestry systems. Similar trend of results were noted in case of fruit yield of bottle gourd where the highest yield per plant (25.13 Kg) and yield per hectare (62.83 tons) were recorded in open field (non-agroforestry). In case of individual fruit size and weight, significantly the lowest values were noted in mango-based agroforestry system. However, the largest individual fruit weight was recorded in the non-agroforestry system, which was similar to that in the sweet orange-based agroforestry system. These findings suggest that there was a severe competition between the trees and the crops as they struggled for essential resources; though the fruit length, diameter and single fruit weight had no significance difference between the open field and orange tree. Anwar *et al.* (2013) also observed a decreased trend of bottle gourd yield when it was cultivated in proximity to Akashmoni trees.

Performance of stem amaranth

In Kharif-I season, stem amaranth production was slightly varied between agroforestry and non-agroforestry systems except plant height (Fig. 3). Notably, the tallest (68.00 cm) and the shortest (60.67 cm) plants of stem amaranth were recorded in open field and the mango-based agroforestry system, respectively. Furthermore, the weight of an individual stem amaranth stalk and the yield per hectare were also lowest in the mango-based agroforestry system; however, the stalk weight and yield per ha in both mango and orange-based agroforestry system remained statistically similar (Fig. 3). According to the findings, there appears to be minimal competition between fruit trees with stem amaranth. Comparatively, stem amaranth has a shallow root system than the other tested vegetables. So, there may not be much competition for resources with the fruit trees. However, these results support the expectation that stem amaranth can achieve the anticipated yield when cultivated alongside mango and orange trees. Moreover, Alam et al. (2012) found that weight of amaranth plant was statistically comparable when grown with mango trees.

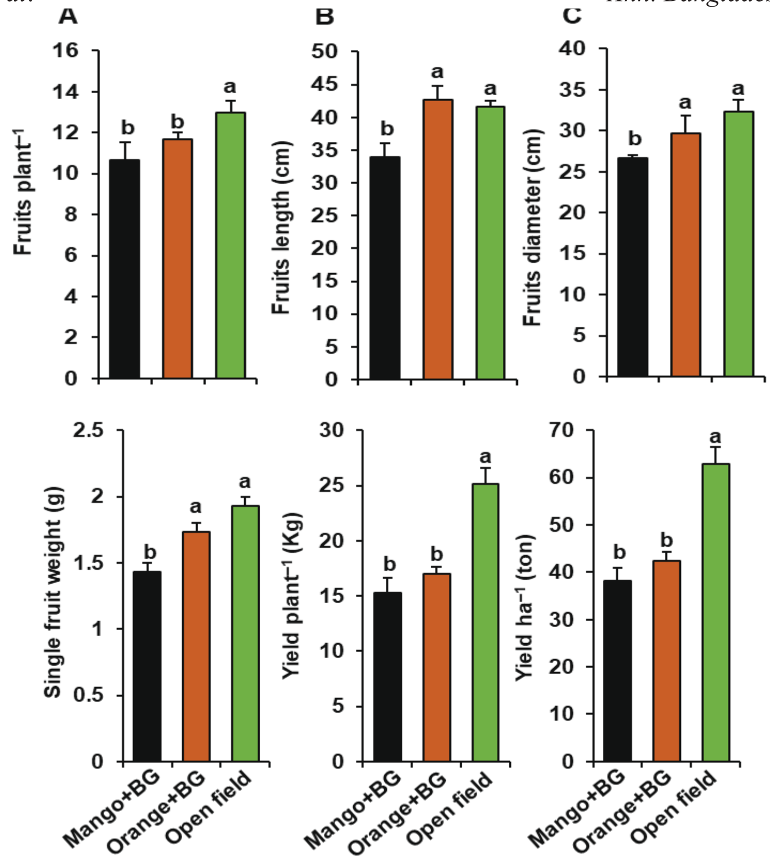

Fig. 2. Yield and yield contributing parameter of bottle gourd (BG) grown in mango and orange-based agroforestry systems, and open field (non-agroforestry). [Values are means ± standard errors of three replicated plots. Bar graphs under a parameter having the same letter(s) above different bar do not differ significantly for LSD (*P* < 0.05);].

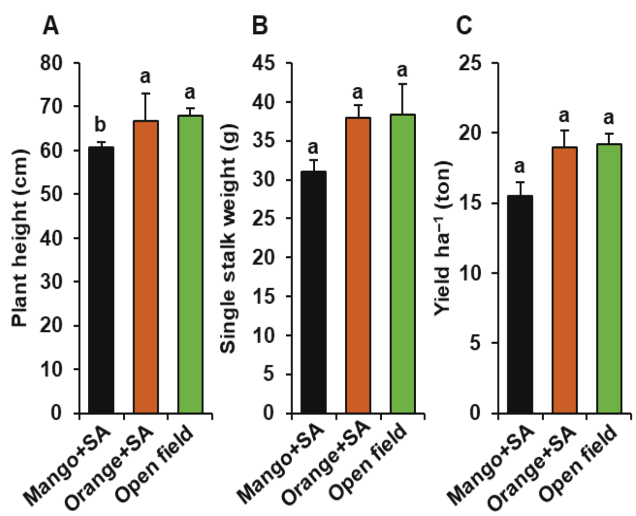

Fig. 3. Stem amaranth (SA) performance in mango and orange-based agroforestry systems including open field. [Values are means ± standard errors of three replicated plots. Bar graphs under a parameter having the same letter(s) above different bar do not differ significantly for LSD (P < 0.05);].

Performance of cauliflower

Performance of cauliflower in different agroforestry and non-agroforestry systems showed slight variations during the Rabi season. The curd length and diameter of cauliflower showed no significant differences between the agroforestry and non-agroforestry (open field) systems. The highest weight of individual cauliflower curd (521.67 g) and the yield per hectare (52.17 tons) were noted in open field. On the other hand, the yield of cauliflower in agroforestry systems were lower than mono agroforestry open field.

Performance of country bean

Country bean was evaluated in mango and orange orchards including open field to investigate the performances in respect of yield and yield-contributing characteristics. There were a significant difference between agroforestry and the non-agroforestry (open field) systems. Significantly the largest pod size (length and width) and highest pod yield were noted in open field compared to agroforestry systems. The maximum pod length (13.86 cm), pod width (8.58 cm), ten pod weight (94.57 g), yield per plant (5.56 Kg), and yield per hectare (5.79 tons) were obtained in open field condition. The significant reduction of yield and yield-contributing characteristics of country bean agroforestry systems might be due to the high competition of water and nutrients between fruit tress and crops (Fig. 5).

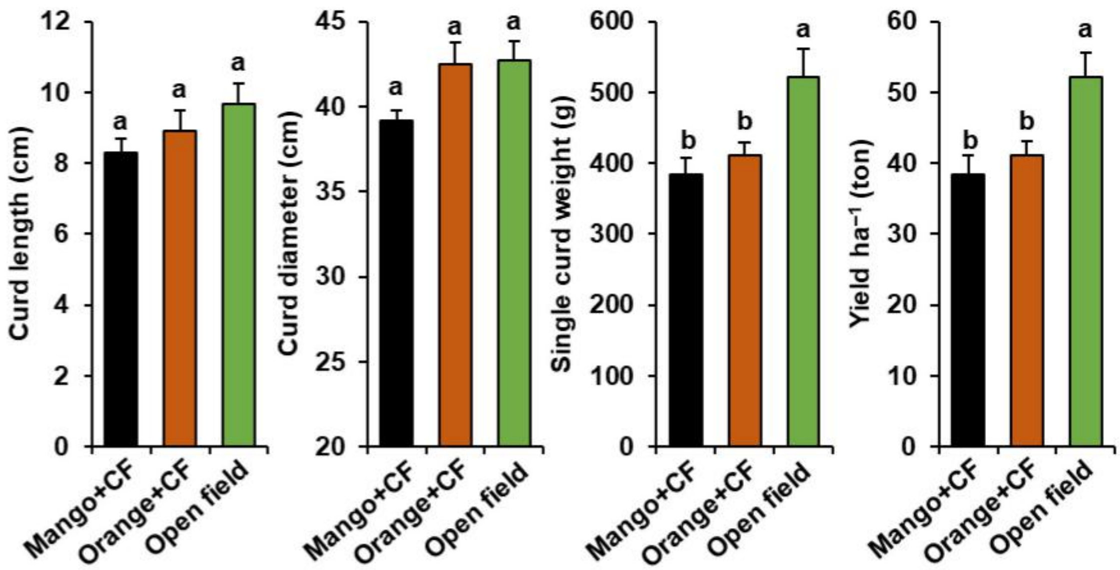

Fig. 4. Cauliflower (CF) performance in mango and orange-based agroforestry systems including open field. [Values are means ± standard errors of three replicated plots. Bar graphs under a parameter having the same letter(s) above different bar do not differ significantly for LSD ($P < 0.05$);].

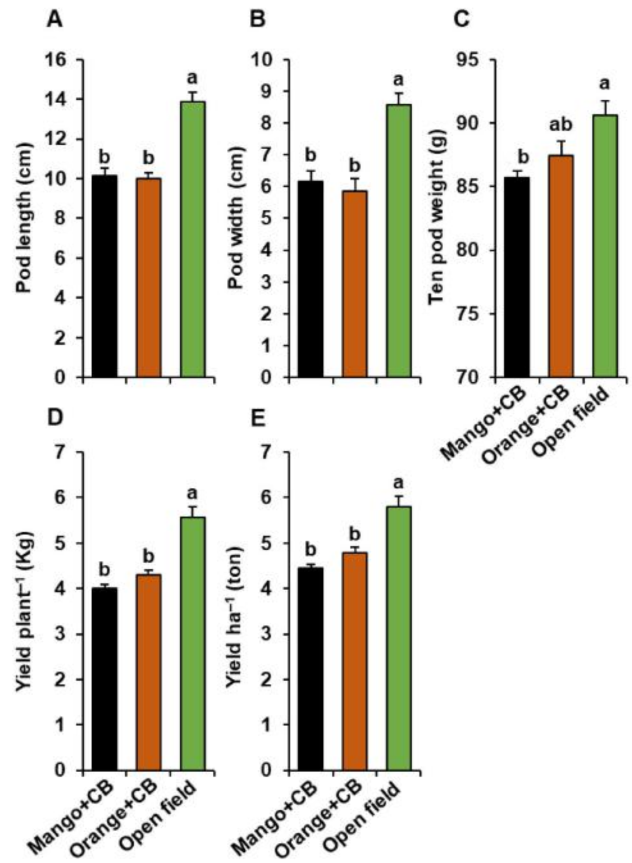

Fig. 5. Country bean (CB) performance in mango and orange-based agroforestry systems including open field. [Values are means ± standard errors of three replicated plots. Bar graphs under a parameter having the same letter(s) above different bar do not differ significantly for LSD (*P* < 0.05);].

Conclusion

The BSMRAU developed vegetables (bottle gourd, stem amaranth, cauliflower, and country bean) were successfully grown as understory crops in mango and orange-based agroforestry systems. The yields of the tested vegetables were slightly lower in agroforestry systems than the non-agroforestry (open field) systems. Moreover, in case of agroforestry systems, crop yields were higher when grown in association with orange trees compared to mango trees. However, BSMRAU-released crop varieties need to be tested with other agroforestry practices at different agro-ecological zones of Bangladesh considering the economic and ecosystems valuations.

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Authors' contributions

Planning, designing and conceptualization were made by M.A.R. and S. R. S. Data collection, curation, analysis, preparation of Figures, discussion and explanation were made by A.K.D, M.A.R. and C.M. Manuscript preparation and editing were made by M.A.R, S.R.S and A.K.D.

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