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RESEARCH PAPER

Winter vegetables cultivation as intercropping with dragon fruit plant under agroforestry approach

Farhana Islam[1], Md. Abdul Wadud[1*], Nasima Akther Roshni[1], Mohammad Kamrul Hasan[1], Md. Masudur Rahman[2] and G. M. Mujibar Rahman[1]

[1]Department of Agroforestry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[2]Department of Agroforestry, Patuakhali Science and Technology University, Patuakhali-8602, Bangladesh

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*Corresponding author:
awadudaf@bau.edu.bd

ABSTRACT

The study was conducted in the 'Agroforestry field laboratory' of Bangladesh Agricultural University, Mymensingh from September 2020 to June 2021. This research study was an agroforestry approach where five winter vegetables viz. spinach, red amaranth, mustard, radish, and turnip with dragon plants. In this study, the two-year-old previously established dragon plants were used as silvicultural components. The planting spacing of the dragon plantation was 3 m × 3 m. Dragon plants were planted in the previously prepared pit. In each pit, three dragon seedlings were planted keeping an RCC pillar in the center of the pit. Winter vegetables were cultivated surrounding the dragon pillar following the Randomized Block Design (RBD) with three replications. Performances of all studied winter vegetables were observed at different distances from dragon plants pits viz. 0-50cm, 51-100cm and 101-150cm in all directions, considered the different treatments of this study. Winter vegetables and dragon plants were also cultivated as sole crop which was considered as the control treatment for agricultural and silvicultural components. Yield and yield contributing attributes of dragon plants were also observed under sole crops and intercrops. As evidence from the result of this study, it was found that the yield of all studied winter vegetables was significantly influenced by dragon plants. Generally, it was found that the growth and yield of all studied winter vegetables gradually decreased towards the base of the dragon pillar. The average yield reduction of studied all winter vegetables at 0-50, 51-100 and 101-150 cm were 64.75, 20.80 and 1.81%, respectively. The average of all treatments for spinach, red amaranth, mustard, radish, and turnip was 28.20, 28.51, 25.23, 34.08 and 29.36%, respectively compared to sole cultivation of each. Yield and yield attributes of dragon plants were not significantly affected by any studied winter vegetables. The average yield of dragon plants with all studied winter vegetables was 26.01 t ha^{-1} and it was 27.10 t ha^{-1} under sole cultivation of dragon plants. Land Equivalent Ratio (LER) for spinach - dragon, red amaranth - dragon, mustard - dragon, radish - dragon and turnip–dragon are 1.67, 1.68, 1.71, 1.62 and 1.66, respectively, which indicates 62-71% yield advantage i.e., under monocultures, 62-71% more land would be needed to match yields from this intercropping.

Key words: Agroforestry, intercropping, winter vegetables, dragon plant

Introduction

The United Nations Development Programme (UNDP) classifies Bangladesh as a least developed country (LDC). It has a population of 170 million people and is spread out over a total area of 1,47,570 square kilometers, with a growth rate of 1.02% each year (BBS, 2019; Reza *et al.*, 2022). According to the World Bank (2019), the country's per capita land area has been steadily declining at an alarming rate, going from 0.174 hectares in 1961 to 0.046 hectares in 2019. In light of these concerning circumstances, it is imperative that an appropriate alternative farming system be identified and implemented in order to remedy the current predicament. The country needs to build an intercropping or combined production system that integrates trees and cropland into what is being referred to as an agroforestry system because there is no room for growing either the forest or the cropland portions of the country. According to Dollinger and Jose (2018), the practice of incorporating trees, crops, and/or animals into an agroforestry system has the potential to increase agricultural output, enhance the soil's nutrient status, reduce erosion, improve air and water quality, and assist in the conservation of biodiversity. Agroforestry, which can optimize nutrient cycling and have favorable effects on soil characteristics, can have a significant impact in terms of boosting total biomass output, crop yield, improved environmental conditions, and improved economic conditions for farmers (Bari, 2019).

Agroforestry has huge potential in Bangladesh. The homestead, roadside, railway side, embankment side, char land, coastal region, deforested area, institutional premises, riverbank, etc. are the key venues for agroforestry. While agroforestry has been practiced for centuries in Bangladesh, the country could profit much more if the best tree-crop combinations were systematically identified and implemented. Vegetables (spinach, red amaranth, mustard, radish, turnip, bottle gourd, etc.) are grown in vast quantities in Bangladesh's plainlands during the winter months, although this is not usually done in conjunction with trees or other plants as part of an agroforestry system. In order to meet the rising demand for fresh produce, Bangladesh urgently needs to ramp up its vegetable and fruit tree plantations. The conservation of natural resources and the preservation of biodiversity both rely heavily on afforestation efforts in Bangladesh. Vegetable crop failures are common in irrigated areas due to insect infections and disease or because prices rise and fall based on supply and demand. Therefore, it was recommended to practice combined practices in which two or more crops are grown with woody components on the same piece of land at the same time. Many researchers have shown that intercropping different vegetable crops provides important advantages and higher profitability than vegetables grown as sole crops (Mallick *et al*., 2013; Alam *et al*., 2014; Das *et al*., 2020; Alam *et al.*, 2021).

The popularity of dragon fruit, a type of tropical fruit, has been on the rise in recent years. Although it's distinct appearance and crunchy flavour are what draw most fans. Pitahaya, often known as dragon fruit, refers to the fruit of the cactaceous plant genus Hylocereus (Reza *et al*., 2022). This plant originally grew in southern Mexico, but it was brought to Central America by European colonists. These cacti are grown in many different places, including the Canary Islands, Cyprus, the United States, Israel, Australia, and Thailand and Vietnam in Southeast Asia. *Hylocereus undatus* (white fleshed dragon fruit) and *Hylocereus costaricensis* (red fleshed dragon fruit) are just two of the many *Hylocereus* species that can be used to make Pitahaya (Sonawane, 2017). While white pulp with black seeds is the most frequent variant, red pulp and yellow pulp with black seeds are also available, but in far lower quantities. The dragon fruit is low in calories while also being rich in fiber and a number of essential vitamins and minerals. It's high in antioxidants, which prevent cell damage. Among these are flavonoids, hydroxycinnamates, and betalains. The prebiotic fiber found in dragon fruit may improve metabolic health by encouraging the growth of good bacteria in the stomach. Farmers in Bangladesh are increasingly interested in cultivating dragon fruit (*Hylocereus spp.)* because of its great economic worth. This fruit plant has promising potential in an agroforestry system. The vertical growth habit of the dragon plant creates a natural canopy, providing shade that helps moderate temperature extremes and prevent frost damage to winter vegetables. Additionally, the dragon plant's root system promotes soil aeration and nutrient cycling, further benefiting the overall health of the intercropped system.

The benefits of intercropping winter vegetables with the dragon plant extend beyond environmental considerations. This agroforestry approach also aids in pest and disease management. The dragon plant emits chemical compounds that act as natural insect repellents, reducing the occurrence of pests that commonly affect winter vegetable crops. Moreover, the diverse plant species in an intercropping system attract a wide range of beneficial insects, such as pollinators and predators, creating a balanced ecosystem that helps control pest populations without relying on synthetic pesticides. In Bangladesh, several studies related to vegetable cultivation under different tree species have already been done, but winter vegetable cultivation with dragon plants as intercropping is rare. Therefore, this study conducted to observe the performance of different winter vegetables namely spinach, red amaranth, mustard, radish, and turnip in association with dragon plants by using agroforestry approach.

Materials and Methods

Study site and period: This research study was conducted on field laboratory of Agroforestry department, Bangladesh Agricultural University, Mymensingh during September 2020 – June 2021.

Dragon plants establishment: In this study the two-years-old previously established dragon plants were used as plant components. Spacing of dragon plant was 3m×3m which were planted in the previously prepared pit. In each pit three dragon seedlings were planted keeping a RCC pillar in the center of pit. In the top of each RCC pillar a used tyre of car wheel was placed for easily fruit of dragon management purpose.

Vegetables or Crops materials: In this study five winter vegetables viz. Spinach (*Spinacia oleracea*), Red Amaranth (*Amaranthus cruentus*), Mustard (*Brassica nigra*), Radish (*Raphanus sativus*) and Turnip (*Brassica rapa*) were cultivated in association with dragon plants as agroforestry approach. The variety of Spinach, red amaranth, mustard, radish and turnip were Copi Palang, BARI Lalshak -1, BARI Shorisha-9, BARI Mula-1 and White Flat, respectively

Experimental design, layout and treatment combination: Five winter crops such as spinach, red amaranth, mustard, radish and turnip were laid out following the Randomized Block Design (RBD) with single factorial arrangement with three replications surrounding the Dragon plants. Individual plot size was 3m×3m. Growth and yield of all studied winter vegetables were observed in different distances from dragon plants pits viz. 0-50cm, 51-100cm and 101-150cm in all directions which were considered as the different treatments of this study. All studied winter vegetables were also cultivated without dragon plant combination which was treated as control treatment of this research study. So, four treatment was considered for each winter vegetables were (i) T_0 = Crop without dragon, (ii) T_1 = 0-50cm distance from the dragon pit, (iii) T_3 = 51-100cm distance from the dragon pit, and (iv) T_4 = 101-150cm distance from the dragon pit. Overall layout of the experiment is shown in Fig. 1.

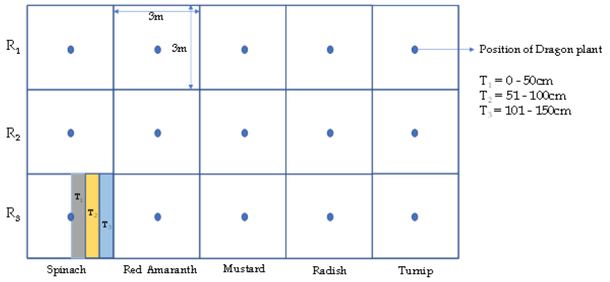

Figure 1. layout of the experiment

Vegetables cultivation: All studied winter vegetables were grown as intercrops in association with dragon plantation as agroforestry practice (Fig. 2). After land preparation seeds of all winter vegetables were sown by using broadcast (spinach, red amaranth and mustard) and dibbling (radish, turnip) from 15 to 25th October. The seeds of these winter vegetables were collected from BADC authorized shop Mymensingh. After sowing of all studied winter vegetables/crops necessary cultural operations viz. weeding, thinning, gap filling, irrigation was done for each crop in proper time.

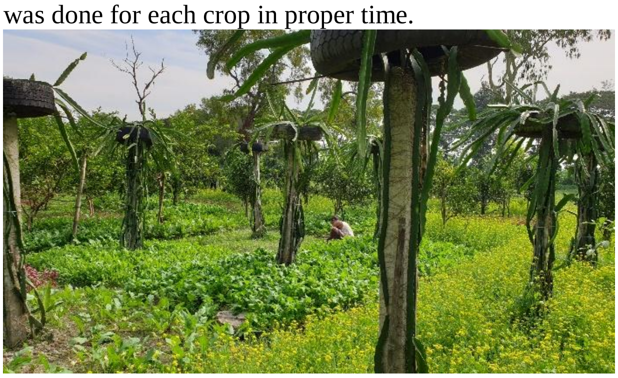

Figure 2. Winter vegetables cultivation in association with dragon fruit plantation

Harvesting, Sampling and data collection: All studied winter vegetables namely spinach, red amaranth, mustard, radish and turnip were harvested for data collection at maturity period. Similar type of parameters were recorded for all studied winter vegetables or crops. Representative samples were collected for data collection. In case of spinach, red amaranth and mustard randomly 10 plants m^{-2} area and in case radish and turnip randomly 5 plants m^{-2} area were collected for data collection. Recorded data were weight per for leafy vegetables and root weight for root crops. Recorded data were estimated as yield (t/ha).

Data collection from Dragon plants: Fruit information from dragon plants were also recorded in association with all studied winter vegetables. Number of fruits per pillar, fruit length (cm), fruit girth (cm) and weight per fruit (g) were measured. The yield of dragon plant was estimated per plant as well as t/ha.

Comparative vegetable yield reduction: In this study, for cultivated winter vegetables yield reduction (%) was estimated using the following formula.

$$\% \text{ Yield reduction} = \left[\frac{\{\text{Yield without tree (t/ha)}\} - \{\text{Yield with tree (t/ha)}\}}{\{\text{Yield without tree (t/ha)}\}}\right] \times 100$$

Land Equivalent Ratio (LER) estimation: LER is the sum of relative yields of the component's species under agroforestry practice where the relative yield of a component is the ratio of 'yield as intercrop' and 'yield as sole crop' on the same unit of land. If LER = 1, there is no advantage (i.e., neutral) to intercropping or agroforestry in comparison to sole cropping. If LER > 1, indicate better use of resources or positive interaction between the components. If LER < 1, indicate the competition i.e., negative interactions between the components. LER was determined by using the following equation:

$$\text{LER} = \sum_{i=1}^{m} (yi \div yii)$$

Where 'yi' is the yield of the 'i' th component from a unit area of the intercrop; 'yii' is the yield of the same component grown as a sole crop over the same area; and (yi ÷ yii) is the relative yield of component i. LER for all studied winter vegetables combination with dragon plants were estimated.

Data analysis: The recorded data were compiled and analyzed by RCBD design to find out the statistical significance of the experimental results. That means for all recorded data, the analyses of variance for all the characters and Least Significant Difference (LSD) test were performed using statistical package programmed Statistix 10.0 software. Mean comparisons were done by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) and also by Least Significant Difference (LSD) test.

Results and Discussion

Performance of winter Vegetables:

Yield performance: Yield performances of all studied winter vegetables were significantly influenced by dragon fruit plants at different distances from its base (Fig. 3). General trend of yield variation of spinach, red amaranth, mustard, radish and turnip was almost similar and it was gradually increase with increasing distances from dragon plant base (Fig. 3).

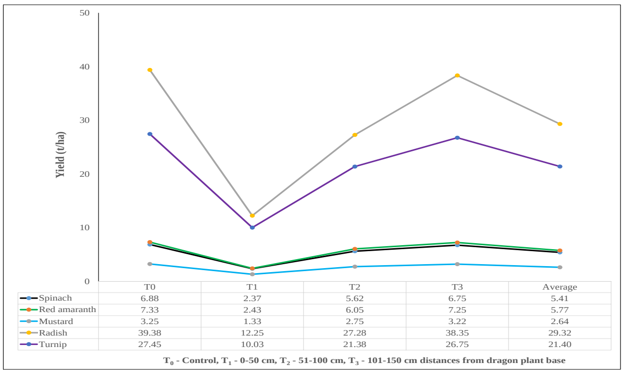

Figure 3. Yield of winter vegetables with dragon plant as intercrops under agroforestry approach

Highest of all studied winter vegetables/crops were recorded in control condition i.e. without dragon fruit plant integration and the values for spinach, red amaranth, mustard, radish and turnip were 6.88, 7.33, 3.25, 39.38 and 27.45 t/ha, respectively (Fig. 3). Among the different distances from dragon plant base yield of all above vegetables were highest at 101-150 cm distance areas which were almost statistically identical with yield produced under control condition for each vegetables/crops. The yield values of spinach, red amaranth, mustard, radish and turnip at 101-150 cm distances from dragon plant were 6.75, 7.25, 3.22, 38.35 and 26.75 t/ha, respectively. Second highest yield for all above vegetables/crops were found in the 51-100 cm distance areas from dragon fruit plant base and the yield values were 5.62, 6.05, 2.75, 27.28 and 21.38 t/ha, respectively (Fig. 3). Remarkably reduced yield values for spinach, red amaranth, mustard, radish and turnip were observed very near i.e. 0-50 cm areas from dragon fruit plant base and these yield values were 2.37, 2.43, 1.33, 12.25 and 10.03 t/ha, respectively (Fig. 3). Average yield (average of yield obtained from treatment T_1, T_2 and T_3) of spinach, red amaranth, mustard, radish and turnip were 5.41, 5.77, 2.64, 29.32 and 21.40 t/ha, respectively (Fig.3).

Yield reduction (%): Yield reduction was estimated separately for different treatments as well as for average yield also. It was found that yield of all studied vegetables severely reduced at 0-50cm distance areas and percent yield reduction values were for spinach, red amaranth, mustard, radish and turnip were 66.55, 66.75, 59.08, 68.89 and 63.46%, respectively (Table 1). Yield reduction values in the 51-100 cm distances areas for spinach, red amaranth, mustard, radish and turnip were 18.31, 17.46, 15.39, 30.72 and 22.115, respectively. Minimum or non-significant yield reduction was found in 101-150cm distance areas from dragon fruit plant base and the values were only 1.89, 1.09, 0.92, 2.62 and 2.55%, respectively. Average percent yield reduction (average of yield obtained from treatment T_1, T_2 and T_3) of all above vegetables/crops were 28.20, 28.51, 25.23, 34.08 and 29.36%, respectively (Table 1).

Table 1. Yield reduction (%) of different winter vegetables in association with dragon plants as agroforestry approach

Treatment	Spinach	Red Amaranth	Mustard	Radish	Turnip
T_1 (0-50cm)	65.55	66.75	59.08	68.89	63.46
T_2 (51-100cm)	18.31	17.46	15.39	30.72	22.11
T_3 (101-150cm)	1.89	1.09	0.92	2.62	2.55
Average	28.20	28.51	25.23	34.08	29.36

During this study period, dragon fruit plant were in fruit bearing stage. So, its root and shoot system was expanded explore more areas for growth resource viz. light, water and nutrients (Franzel *et al*., 1996). Dragon fruit plants root system horizontally spread parallel to the ground (Krisnawati *et al.*, 2011) and also deep thrusting (Groot and Soumare, 1995). As a result, competition for moisture and nutrients may be prominent near the base of dragon fruit plant which might the reasons for lower yield and severe yield reduction very near the base of dragon fruit plant (Jianping *et al.*, 1994). Due to the above facts, the performance of all tested winter vegetables significantly reduced very near the dragon fruit plant. Bellow *et al*. (2008) also support that due to tree-crop interaction effects yield of associated crops is significantly reduced. Ahmed *et al*. (2018), Hasan *et al.* (2013), and Tanni *et al.* (2010) opined that root crop growth was significantly reduced with two years old Guava, Lohakat (*Xylia dolabriformis*), and Eucalyptus tree species.

Performance of dragon plants:

Yield of dragon fruit plants also observed under this agroforestry practice and non-agroforestry practice (Fig. 4). In association with spinach, red amaranth, mustard, radish and turnip different yield attributes of dragon plants are shown in Table 2. As evidence from the results of this study it was found that yield (Fig 5.) and yield attributes (Table 2) of dragon plants significantly similar under agroforestry and non-agroforestry practices with associated cultivated vegetables. Numerically slightly higher number of fruits per pillar, fruit length (cm), fruit girth (cm) and individual fruit weight (g) of dragon plants was observed in without vegetables combination and values were 32.33, 14.25 cm, 28.75 cm and 335.33 g (Table 2). Yield of dragon plants under non-agroforestry practice was 27.10 t/ha which almost similar with the yield produced in association with spinach, red amaranth, mustard, radish and turnip and the yield values were 25.95, 26.68, 26.84, 25.95 and 26.63 t/ha, respectively (Fig 5). Average yield of dragon plants with all vegetables was 26.01 t/ha (Fig 8). This minimum or non-significant difference may be due to intensive management of winter vegetables which minimize competitive effect of dragon plant. Non-significant yield difference also found by Alam *et al.* (2014) when they combinedly cultivated winter vegetables and sapling stage of Akashmoni trees.

Figure 4. Dragon fruits under intercropping with winter vegetables as agroforestry approach

Table 2. Yield attributes of dragon plants as agroforestry approach

Associated vegetables	Fruit information			
	No. of fruits per pillar	Fruit length (cm)	Fruit girth (cm)	Individual fruit weight (g)
Spinach	31.00	13.35	28.26	334.78
Red Amaranth	32.00	12.75	28.43	333.56
Mustard	32.33	13.25	27.68	332.05
Radish	31.33	12.87	27.23	331.34
Turnip	30.00	12.57	26.95	328.45
Without vegetables	32.33	14.25	28.75	335.33
Level of significance	NS	NS	NS	NS

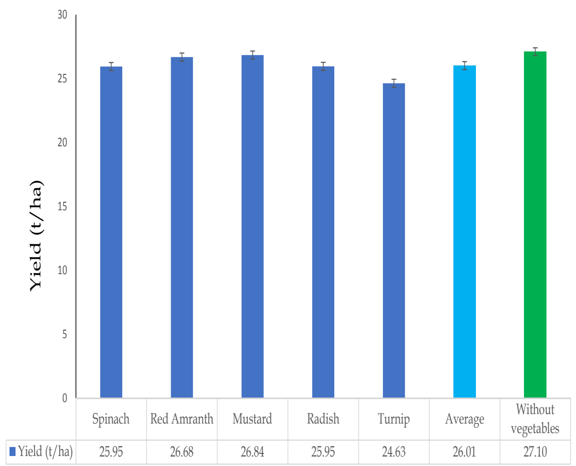

Figure 5. Yield of dragon fruit plant as intercrops with winter vegetables as agroforestry approach

Land Equivalent Ratio (LER) analysis:

LER was estimated from the relative yield (RY) of dragon plants and vegetable components involved in this study. Estimated RY of dragon plant is 0.96 and it is for spinach, red amaranth, mustard, radish and turnip 0.71, 0.72, 0.75, 0.66 and 0.70, respectively (Table 3). LER for Dragon-Spinach, Dragon-Red Amaranth, Dragon-Mustard, Dragon-Radish and Dragon-Turnip are 1.67, 1.68, 1.71, 1.62 and 1.66, Respectively (Table 3) which indicates 62-71% yield advantage i.e., under monocultures, 62-71% more land would be needed to match yields from this intercropping. Akter *et al.* (2020) also successfully evaluates different crop combinations under a multistoried agroforestry system in the Madhupur Sal forest based on LER analysis.

Table 3. Land Equivalent Ratio (LER) of Dragon plant based intercropping as agroforestry approach

Crop Combinations	Relative yield		LER (a+b)
	Vegetable (a)	Dragon plant (b)	
Dragon-Spinach	0.71		1.67
Dragon-Red Amaranth	0.72		1.68
Dragon-Mustard	0.75	0.96	1.71
Dragon-Radish	0.66		1.62
Dragon-Turnip	0.70		1.66

Based on the findings of this study it may be concluded that intercropping with winter vegetables and dragon plants will be a profitable farming practice by using the agroforestry approach.

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