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RESEARCHARTICLE

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Seed Yield and Quality of Carrot (*Daucus carota* L.) in Response to Intercropping with Different Vegetables

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Abstract

Carrot (*Daucus carota* L.) is an important crop that is grown through seed. In Pakistan, availability of locally produced vegetable seed of high quality is scarce. Our farmers cannot afford to produce seed on their farms because of long duration of seed crops and less income as compared to farming for fresh production. To tackle with this problem intercropping in carrot seed crop was evaluate. In this proposed experiment, carrot was intercrop with coriander, turnip, radish and onion. The experiment had been organized in vegetable area of Institute of Horticulture Sciences, University of Agriculture, Faisalabad. Varieties used for this experiment were as follow: T-29 of carrot, Dilpasand of coriander, Purple top of turnip, All Season of radish and Phulkara of onion. This experiment was conduct under Randomized Complete Block Design (RCBD). The cultivated area had been divided into four blocks. Each block contained five treatments, i.e. four intercrops and one treatment comprising sole carrot seed crop. Data for various parameters of carrot and yield of intercrops collected at harvesting stage. Germination test of carrot seeds conducted in growth room of Department of Seed Science and Technology. Statistical analysis had been done using Statistix 8.1. LSD test was applied to compare the mean values of different treatments. Plant height and benefit cost ratio was increased when carrot seed crop intercropped with turnip all other characters i.e. number of secondary and tertiary umbels per plant, seed weight of primary, secondary and tertiary umbels, 1000 seed weight of primary, secondary and tertiary umbels, seed weight per plant, seedling length, fresh and dry weight and vigor index of all order umbels were decreased. The minimum value for plant height and benefit cost ratio and the maximum values for number of secondary and tertiary umbels per plant, seed weight of primary, secondary and tertiary umbels, 1000 seed weight of primary, secondary and tertiary umbels, seed weight per plant, seedling length, fresh and dry weight and vigor index of all order umbels was observed from sole carrot seed crop. Germination % was not affected by any treatment of intercropping. It was concluded that turnip was recommended as best intercrop with maximum benefit cost ratio.

KEYWORDS
Carrot seed crop, Intercropping of vegetables, Benefit cost ratio

1 | INTRODUCTION

The essential human diet that provided mineral elements, vitamins, carbohydrate and protein are vegetables. There are number of vegetables that can be cultivated in Pakistan. The major vegetable crops grown in Pakistan are given as carrots, tomato, onions, melons, cabbage, cauliflower, turnips, cucurbits and potatoes etc. Carrot is considered an important crop in Pakistan and was cultivated on an area of 13.38 thousands ha with production of 227.07 thousand tons (Government of Pakistan, 2015-2016).

Carrot (*Daucus carota* L.) is a root vegetable cultivated in world and Pakistan, which has many

antioxidants, vitamins, especially vitamin A, and beta carotene (Leja et al., 2013). Carrot is also a factory of vitamin E, B, H, C, pantothenic acid and folic acid. It also contains trace elements i.e. Fe, K, Mg, Na, Zn, Mn, Cu, Ca, P and S. It is useful to lowers the level of cholesterol, to improve digestion and to improve eyesight (Bystrická et al., 2015). In Pakistan less attention has been paid for production of carrot seed. That's why carrot production is less in Pakistan as contrast to other countries. In Punjab province, carrot production is 17.65 tons/h but worldwide is 30 tons/h. So there is a gap of 41.6% (Khokhar, 2014). Absence of best quality seed is the main factor behind it. The seed of commercial carrot cultivars is not available for farmers at cheaper price. So, it is need of time to introduce high quality carrots that are good in yield and as well as in seed production (Tabor et al., 2016).

Carrot is raised by direct seeding in the field and therefore, demands high quality seeds for obtaining good crop stand. The seed quality of carrots is based on several factors, namely, the climatic condition of the area (George, 2009), soil health and fertility (Ilyas et al., 2013), steckling size and umbel position on mother plant (in which seed is produced) (Anjum and Amjad, 2002). The plant of carrot go towards reproductive phase when grow for seed production. The flower of the carrot plant is known as umbel. There are present three orders of umbels on one plant of carrot and these umbels are known as primary, secondary, and tertiary umbels according to their order of development on the plant. The type of umbel develop on main stem is taken as primary umbel, secondary umbels derived from the primary umbel and the tertiary umbels grow on the branches develop from secondary branches. It was also observed that the seeds obtained from superior umbels are good in quality and health than that of the seeds obtained from secondary and tertiary umbels (Pereira et al., 2008).

Its seed can be produced by direct (seed-to-seed method) and indirect (root-to-seed) scheme. In direct or seed-to-seed method, less expenditure is insured and yield is high. But, quality of root can't be assessed without uprooting of carrots. So, seed-to-seed method can't guarantee about quality of root produced and the seed produced by this method may produce carrots of low quality in terms of root size (length and diameter) as well as internal and external color. While, in root-to-seed method, carrots are uprooted after root maturity and therefore proper rouging (removal of off-type or undesirable roots) can be performed. But, cost of seed production is increased because of extra labor involved in uplifting of roots and replanting of stecklings (Singh, 1999). Moreover, seed yield is decreased a little bit and seed maturity is decreased by 10-15 days (George, 2009). Because of these reasons, farmers and some local seed companies prefer seed-to-seed method and produce poor quality seed.

It has been observed that after replanting of carrot stecklings in root-to-seed method, re-growth (formation adventitious roots and new leaves) starts after a few days, depending upon climatic conditions of the area. While, first seed stalk (primary umbel) appears after about 30-45 days under the agro-climatic conditions of Faisalabad. Till that time, space between two stecklings is free and can be efficiently utilized by growing short duration and shallow rooted inter-crops.

Intercropping is the production of more than one crop sown in the same land at the same time. Intercropping is a way to enhance diversity in an agricultural ecosystem, thereby, increasing the use of resources, product quantity and quality, and environmental balance, ultimately increasing the benefit-cost ratio (Mousavi and Eskandari, 2011). Coriander, radish, onion and turnip are short-stature and short-duration crops having shallow root system. Those crops are preferred as inter-crops which do not compete with the main crop. Moreover inter-specific interaction in the rhizosphere can also affect the amount of available and uptake-able nutrients in intercropping (Li et al., 2010). An experiment was proceeded on maize hybrid intercropped with short duration crops i.e. spinach, potato, French bean and lalsak in a field experiment. It was noted that there was low grain yield obtained from maize sole crop while on the other hand there was a great increase or decrease in seed production of maize hybrid when intercropped with short duration vegetables. There was also obtained valuable net benefit cost ratio from that intercropping system (Uddin et al., 2009).

A field experiment on intercropping of different vegetables with different types of seed spices was conducted. In that there were following intercropping systems that had been consisted on pea-fennel, pea-ajwain, pea-coriander, cabbage-fennel, cabbage-ajwain, cabbage-coriander, carrot-fennel, carrot-ajwain and carrot- coriander were sown in randomized complete block design with three replications. That experiment was continued for two years. The results of that study exhibited that the vegetables as pea, cabbage, and coriander perform very well in the aspect of yield when intercropped with fennel rather than intercropping systems of all those vegetables intercropped with coriander and ajwain. The seed yield of ajwain, coriander and fennel was enhanced when intercropped with carrot that was more than that of intercropping of spices with pea and cabbage. Among all the intercropping patterns cabbage and fennel intercropping system gave the highest grain yield to land ratio and net return of fennel crop, it was followed by the intercropping of carrot with fennel. In case of intercropping of cabbage and fennel the highest benefit cost ratio was observed among all other intercropping systems. Intercropping of cabbage with ajwain also gave better yield equivalent ratio and net return (Mehta

et al. 2017). So, keeping in view the dearth of knowledge regarding intercropping in carrot seed crops, this study has been planned with the objectives of estimating the impact of intercropping on the yield and quality of carrot seed and to discover a vegetable that is best suited as intercrop in carrot seed crop.

2 MATERIALS AND METHODS

The experiment was conducted in the vegetable research area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad to evaluate the effects of intercropping of carrot seed crop with coriander, turnip, radish and onion, on yield and quality of carrot seed. Seed of carrot cultivar T-29 was cultivated at 20 August 2017. Roots were harvested at 25 December 2017 and used for steckling preparation after roguing. The stecklings used for this experiment were uniform in size and prepared by detaching lower half portion of the root and leaf blades, keeping growing point on crown intact. The short duration crops used for this experiment were coriander (Dilpasand), turnip (Purple top), radish (All seasons) and onion (Phulkara). The layout for this experiment was randomized complete block design (RCBD) in four blocks. Stecklings were planted in field at 2.5×1ft (R×R and P×P) spacing, during the last week of December 2017. Carrot seed crop was intercropped with other crops as mentioned under and also grown alone as sole crop. Seeds of other crops were sown one week after planting of carrot stcklings. The carrot stecklings were planted on the top of ridges and other vegetables were sown on both sides of the ridges. Treatments were T_0 = Carrot seed crop alone (Sole crop), T_1 = Carrot seed crop + coriander, T_2 = Carrot seed crop + turnip, T_3 = Carrot seed crop + radish, and T_4 = Carrot seed crop + onion. The morphological parameters measured in this experiment were Days to anthesis from the sowing date of the carrot stecklings, plant height, number of secondary umbels, number of tertiary umbels, weight of seeds harvested from the primary umbels, secondary umbels, tertiary umbels, weight of 1000 seeds of primary, secondary, tertiary umbels, weight of total seeds harvested from primary, secondary, and tertiary umbels, Weight of primary, secondary and tertiary umbels seeds in each replicate of every treatment was also measured. A germination test was performed as mentioned earlier. The final germination percentage was calculated by given formula

$$\text{Final germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$$

Ten seedlings from primary, secondary, and tertiary umbels were separately collected from each petri dish and placed on a double layer of tissue paper to remove the water drops from the seedlings. The other parameters i.e. seedling length, seedling vigor index (Abdul-Baki and Anderson, 1973), seedling fresh weight, seedling dry weight obtained from primary, secondary and tertiary umbels were separately measured. For this purpose the selected seedlings whose fresh weight was measured were packed in paper bags and placed in oven at 65 ^{0}C for 48 hours to remove the moisture content from the seedlings (Schmidhalter and Oertli, 1991).

Seedling vigor index = Seedling length (cm) x final germination percentage

The weight of the vegetative portion harvested from the 1st, 2nd, 3rd, and 4th cutting of coriander was measured in grams per plot. Root yield of turnip harvested from each plot was measured and expressed as kg/ft^2. Root yield of radish harvested from each plot was measured and expressed as kg/ft^2. The bulb yield of onion harvested from each plot was measured and expressed as kg/ft^2. The benefit-cost ratio was calculated by comparing total experimental expenditures i.e. cost of seeds, fertilizer, irrigation, spray, and labor with economic outputs obtained from the experiment.

Statistical analysis

The obtained data were subjected to analysis of variance (Steel et al. 1997) by using Statistix 8.1. Significant difference among treatments will be determined by employing LSD test at 5% probability level.

3 RESULTS

Morphological Parameters at Maturity Stage

Analysis of variance exhibited that all morphological traits for different intercropping patterns were significantly different from each other and non-significant for most of the traits in blocks (Table 1). The maximum value for carrot plant height was noticed when the carrot seed crop was intercropped with turnip (163.14 cm) and onion (163.07 cm) both were statistically similar. Minimum plant height was observed in sole carrot seed crop (without intercropping) (155.07 cm), but was statistically at par with plant height of carrot seed crop intercropped with coriander (160.80 cm) and radish (159.71 cm) (Table 2). These results concluded that plant height of carrot seed crop was significantly affected by intercropping system. Maximum number of secondary umbels per plant was observed from sole carrot seed crop (without intercropping) (8.7), but was statistically at par with carrot seed crop intercropped with coriander (8.4), radish (8.3) and onion (8.1). Minimum number of secondary umbels per plant was observed from carrot seed crop intercropped with turnip (7.7) was statistically at par with carrot seed crop intercropped with coriander, radish and onion (Table 2).

Table 1: Mean squares of morphological parameters of carrot crop

Source	D.F.	PH	NSUP	NTUP	SWP	SWS	SWT	1000 SWP	1000 SWS	1000 SWT	TSYP	TSY
Treatments	4	47.84*	0.50*	13.11*	1.77*	12.37*	7.69*	0.003*	0.006*	0.07**	55.40**	179512*
Blocks	3	0.01^{NS}	0.06*	0.09*	0.06^{NS}	0.01^{NS}	0.16*	0.0002^{NS}	0.0002^{NS}	0.0005^{NS}	0.41^{NS}	32^{NS}
Error	12	0.01	0.01	0.02	0.05	0.06	0.04	0.0002	0.0004	0.002	0.18	120

* = Significant (P<0.05), ** = Highly significant, NS = Non-significant (P<0.01)
D.F: Degree of freedom, PH: Plant height, NSUP: No. of secondary umbels per plant, NTUP: No. of tertiary umbels per plant, SWP: Seed weight of primary umbels, SWS: Seed weight of secondary umbels, SWT: Seed weight of tertiary umbels, TSYP: Total seed yield per plant, TSY: Total seed yield

Table 2: LSD mean comparison of morphological parameters of carrot crop

Treatments	PH	NSUP	NTUP	SWP	SWS	SWT	1000 SWP	1000 SWS	1000 SWT	TSYP	TSY
Sole carrot seed crop	155.07^{B}	8.7^{A}	14.5^{A}	6.3^{A}	18.6^{A}	6.1^{A}	4.67^{A}	4.78^{A}	4.86^{A}	31.14^{A}	1847.6^{A}
Carrot seed crop+Coriander	160.80^{AB}	8.4^{AB}	13.7^{B}	5.8^{B}	16.8^{B}	5.1^{B}	4.64^{AB}	4.76^{AB}	4.83^{AB}	27.76^{B}	1730.9^{B}
Carrot seed crop + Turnip	163.14^{A}	7.7^{B}	9.9^{D}	4.7^{D}	14.2^{D}	2.7^{E}	4.60^{C}	4.69^{C}	4.57^{C}	21.58^{D}	1305.6^{E}
Carrot seed crop + Radish	159.71^{AB}	8.3^{AB}	13.5^{B}	5.5^{BC}	14.7^{D}	3.9^{C}	4.64^{AB}	4.77^{A}	4.60^{C}	24.18^{C}	1564.2^{C}
Carrot seed crop + Onion	163.07^{A}	8.1^{AB}	11.8^{C}	5.1^{CD}	15.8^{C}	3.3^{D}	4.62^{BC}	4.72^{BC}	4.74^{B}	24.17^{C}	1481.3^{D}

Means that do not share a letter are significantly different at P ≤ 5 % level of probability (LSD)
PH: Plant height, NSUP: No. of secondary umbels per plant, NTUP: No. of tertiary umbels per plant, SWP: Seed weight of primary umbels, SWS: Seed weight of secondary umbels, SWT: Seed weight of tertiary umbels, TSYP: Total seed yield per plant, TSY: Total seed yield Germination ANOVA

Maximum number of tertiary umbels was detected in sole carrot seed crop (14.5), the minimum number of tertiary umbels was observed when carrot seed crop was intercropped with turnip (9.9) and onion (11.8) were statistically different from each other. The carrot seed crop intercropped with coriander (13.7) and radish (13.5) was statistically non-significant (Table 2). According to the results obtained from this experiment, the maximum seed weight was observed from the sole carrot seed crop (6.3 g) was statistically different from all other treatments. The lowest seed weight from primary umbel was observed when carrot seed crop intercropped with turnip (4.7 g) was statistically at par with carrot seed crop intercropped with onion (5.1 g) that was also at par with carrot seed crop intercropped with radish (5.5 g). On the other hand carrot seed crop intercropped with coriander (5.8 g) was statistically at par with carrot seed crop intercropped with radish (Table 2). The maximum value was observed for the seed weight of secondary umbels in sole carrot seed crop (18.6 g), carrot seed crop intercropped with coriander (16.8 g) and onion (15.8 g) were statistically different from each other. Minimum value for the seed weight of secondary umbels was observed when intercropping of carrot seed crop was done with turnip (14.2 g) and radish (14.7 g), both was statistically similar (Table 2). The maximum value for the seed weight of tertiary umbels was recorded for sole carrot seed crop (6.1 g), carrot seed crop intercropped with coriander (5.1 g), radish (3.9 g), onion (3.3 g) and the minimum value for seed weight of tertiary umbel was observed when carrot seed crop was intercropped with turnip (2.7 g) were statistically different from each other (Table 2). The maximum value for 1000 seed weight of primary umbels was obtained from sole carrot seed crop (4.67 g) was statistically at par with carrot seed crop intercropped with coriander (4.64 g) and radish (4.64 g). The minimum value for 1000 seed weight of primary umbels was obtained from the intercropping of carrot seed crop with turnip (4.60 g) was statistically at par with carrot seed crop intercropped with onion (4.62 g) (Table 2). The maximum value for 1000 seed weight of secondary umbels was observed from sole carrot seed crop (4.78 g) was statistically similar to carrot seed crop intercropped with radish (4.77 g) and both were at par with 1000 seed weight of secondary umbels intercropped with coriander (4.76 g). Minimum value for 1000 seed weight of secondary umbels was obtained from carrot intercropped with turnip (4.69 g) was also statistically at par with carrot seed crop intercropped with coriander and onion (4.72 g) (Table 2). The maximum value for 1000 seed weight of tertiary umbels obtained from sole carrot seed crop (4.86 g) that was at par with 1000 seed weigh of tertiary umbels obtained from carrot seed crop intercropped with coriander (4.83 g). The 1000 seed weight of tertiary umbels obtained from carrot seed crop intercropped with onion (4.74 g) was also at par with carrot seed crop intercropped with coriander. On the other hand the minimum value for 1000 seed weight of tertiary umbels obtained from carrot seed crop intercropped with turnip (4.57 g) was statistically similar to carrot seed crop intercropped with radish (4.60 g) (Table 2). The range of the value for total seed carrot seed yield per plant was from 31.14 g to 21.58 g. The maximum value was observed from sole carrot seed crop (31.14 g), carrot seed crop intercropped with coriander (27.76 g) and the minimum value for total carrot seed yield per plant was obtained from carrot seed crop intercropped with turnip (21.58 g) were statistically unlike from each other. The total seed yield per plant of carrot seed crop intercropped with radish (24.18 g) and onion (24.17 g) was statistically non-significant (Table 2). The maximum carrot seed yield per plot was obtained from

sole carrot seed crop (1847.6 g), the minimum carrot seed yield per plot was observed when carrot seed crop intercropped with turnip (1305.6 g) and value for carrot seed yield per plot when carrot seed crop intercropped with coriander (1730.9 g) radish (1564.2 g) and onion (1481.3 g), all of these values were quite different from each other (Table 2). The results showed that intercropping had significant effects on morphological parameters of carrot seed crop.

Morphological Traits at Seedling Stage

Data collected for the seedling of primary, secondary, and tertiary umbels of carrot seed crop was analyzed statistically using analysis of variance technique that exhibited all treatments were different from each other with significant difference (Table 3). The maximum primary umbel seedling length was observed from the seeds obtained from sole carrot seed crop (4.98 cm) statistically at par with carrot seed crop intercropped with coriander (4.78 cm) and radish (4.63 cm), the seedling length of primary umbel obtained from carrot seed crop intercropped with onion (4.43 cm) was also statistically at par with radish intercropping systems and minimum seedling length obtained from carrot seed crop intercropped with turnip (3.70 cm) was significantly different from all other treatments (Table 4).The maximum seedling length of secondary umbels was observed in controlled treatment in which sole carrot seed crop grown (5.3 cm) and the minimum seedling length was observed from the carrot seed crop intercropped with turnip (3.8 cm). The seedling length of secondary umbels was 4.9 cm for both treatments when carrot seed crop intercropped with coriander and radish separately and seedling length for carrot intercropped with onion was 4.8 cm all were statistically non-significant (Table 4). The maximum seedling length of tertiary umbels was observed in sole carrot seed crop (4.9 cm) and minimum seedling length was expressed by carrot seed crop intercropped with turnip (3.8 cm) were statistically at par with carrot seed crop intercropped with coriander (4.6 cm) and radish (4.5 cm) and onion (4.2 cm) respectively (Table 4). The minimum value for primary umbel seedling fresh weight was observed when carrot seed crop intercropped with turnip (12.60 mg) was statistically different from all other treatments. The maximum seedling fresh weight was observed from sole carrot seed crop (14.27 mg) and carrot seed crop intercropped with coriander (13.75 mg) and onion (13.57 mg) all were statistically at par with radish (13.87 mg) (Table 4). The maximum seedling fresh weight of secondary umbel was obtained from sole carrot seed crop (13.00 mg) was statistically same to the carrot seed crop intercropped with coriander (12.67 mg). The seedling fresh weight of secondary umbels of carrot seed crop intercropped with radish (11.95 mg) and onion (11.67 mg) was statistically same. Minimum seedling fresh weight of secondary umbels obtained from carrot seed crop intercropped with turnip (10.85 mg) was statistically different from all other treatments (Table 4). The maximum seedling fresh weight for sole carrot seed crop (9.97 mg) and carrot seed crop intercropped with coriander (9.65 mg) was same. The seedling fresh weight of tertiary umbels of carrot seed crop intercropped with radish (9.15 mg) and onion (8.92 mg) was statistically same. Minimum seedling length of carrot seed crop intercropped with turnip (7.85 mg) was quite different from all other treatments (Table 4). The maximum primary umbel seedling dry weight was obtained from the sole carrot seed crop (1.12 mg), carrot seed crop intercropped with coriander (1.05 mg), radish (1.07 mg) and onion (1.02 mg) were statistically similar to each other. Minimum seedling dry weight of primary umbel was observed when carrot seed crop intercropped with turnip (0.90 mg) was different from all other treatments (Table 4). The maximum secondary umbel seedling dry weight was obtained from the sole carrot seed crop (0.95 mg) and carrot seed crop intercropped with coriander (0.90 mg) was statistically same. The seedling dry weight of carrot seed crop intercropped with radish (0.80 mg) and onion (0.77 mg) was also statistically same. Minimum seedling dry weight was observed when carrot seed crop intercropped with turnip (0.65 mg) (Table 4). The maximum tertiary umbel seedling dry weight was obtained from the sole carrot seed crop (0.70 mg) and carrot seed crop intercropped with radish (0.57 mg), onion (0.55 mg) were statistically different from each other but at par with carrot seed crop intercropped with coriander (0.62 mg). Minimum seedling dry weight was observed when carrot seed crop intercropped with turnip (0.40 mg) was statistically different from all other treatments (Table 4). The maximum germination percentage obtained from sole carrot seed crop (96 %), carrot seed crop intercropped with onion (96 %), coriander (95 %), radish (94 %) and the minimum germination percentage obtained from carrot seed crop intercropped with turnip (92 %) were statistically same for primary umbel. The maximum germination percentage obtained from carrot seed crop intercropped with turnip (97 %), sole carrot seed crop (95 %), carrot seed crop intercropped with onion (95 %) and the minimum germination percentage obtained from carrot seed crop intercropped with coriander (92 %) and radish (92 %) were statistically same for secondary umbel. The maximum value was for carrot seed crop intercropped with radish (92 %), coriander (88 %), sole carrot seed crop (87 %), intercropped with onion (87 %) and the minimum value was for carrot seed crop intercropped with turnip (85 %) were statistically same for tertiary umbel. The maximum primary umbel seedling vigor index was calculated for sole carrot seed crop (476.7), carrot seed crop intercropped with coriander (453.6), radish (434.1) and onion (424.6) were statistically similar.

Table 3: Mean squares of morphological parameters of carrot crop at seedling stage

Source	D.F.	GPP	GPS	GPT	SLP	SLS	SLT	SFWP	SFWS	SFWT	SDWP	SDWS	SDWT	SVIP	SVIS	SVIT
Treatments	4	11.2^{NS}	18.8^{NS}	26.8^{NS}	0.96^{*}	1.14^{*}	0.73^{*}	1.55^{*}	2.88^{*}	2.66^{*}	0.03^{*}	0.05^{*}	0.05^{*}	10710^{**}	8858^{*}	7388^{*}
Blocks	3	32.8^{NS}	49.9^{NS}	60.5^{NS}	0.19^{**}	0.20^{*}	0.10^{NS}	0.05^{NS}	0.003^{NS}	0.15^{*}	0.002^{NS}	0.002^{NS}	0.006^{NS}	1726^{NS}	2236^{NS}	3612^{NS}
Error	12	39.5	27.9	51.9	0.02	0.02	0.06	0.05	0.04	0.04	0.002	0.002	0.002	675	700	1095

* = Significant (P<0.05), ** = Highly significant, NS = Non-significant (P<0.01); D.F: Degree of freedom, GPP: Germination percentage of primary umbels, GPS: Germination percentage of secondary umbels, GPT Germination percentage of tertiary umbels, SLP: Seedling length of primary umbels, SLS: Seedling length of secondary umbels, SLT: Seedling length of tertiary umbels, SFWP: Seedling fresh weight of primary umbels, SFWS: Seedling fresh weight of secondary umbels, SFWT: Seedling fresh weight of tertiary umbels, SDWP: Seedling dry weight of primary umbels SDWS: Seedling dry weight of secondary umbels, SDWT: Seedling dry weight of tertiary umbels, SVIP: Seedling vigor index of primary umbels, SVIS: Seedling vigor index of secondary umbels, SVIT: Seedling vigor index of tertiary umbels

Table 4: LSD mean comparison of morphological parameters of carrot crop at seedling stage

Treatments	SLP	SLS	SLT	SFWP	SFWS	SFWT	SDWP	SDWS	SDWT	SVIP	SVIS	SVIT
Sole carrot seed crop	4.98^{B}	5.3^{A}	4.9^{A}	14.3^{A}	13^{A}	9.9^{A}	1.1^{A}	0.9^{A}	0.7^{A}	476^{A}	504^{A}	431^{A}
Carrot seed crop + Coriander	4.78^{AB}	4.9^{B}	4.6^{AB}	13.8^{B}	12.7^{A}	9.7^{A}	1.1^{A}	0.9^{A}	0.6^{AB}	453^{A}	457^{AB}	410^{A}
Carrot seed crop + Turnip	3.70^{D}	3.8^{C}	3.8^{C}	12.6^{C}	10.9^{C}	7.9^{C}	0.9^{B}	0.7^{C}	0.4^{C}	340^{B}	375^{C}	325^{B}
Carrot seed crop + Radish	4.63^{BC}	4.8^{B}	4.5^{AB}	13.9^{AB}	11.9^{B}	9.2^{B}	1.1^{A}	0.8^{B}	0.6^{B}	434^{A}	440^{B}	416^{A}
Carrot seed crop + Onion	4.43^{C}	4.9^{B}	4.2^{BC}	13.6^{B}	11.7^{B}	8.9^{B}	1^{A}	0.8^{B}	0.6^{B}	424^{A}	465^{AB}	371^{AB}

Means that do not share a letter are significantly different at P ≤ 5 % level of probability (LSD)
GPP: Germination percentage of primary umbels, GPS: Germination percentage of secondary umbels, GPT Germination percentage of tertiary umbels, SLP: Seedling length of primary umbels, SLS: Seedling length of secondary umbels, SLT: Seedling length of tertiary umbels, SFWP: Seedling fresh weight of primary umbels, SFWS: Seedling fresh weight of secondary umbels, SFWT: Seedling fresh weight of tertiary umbels, SDWP: Seedling dry weight of primary umbels SDWS: Seedling dry weight of secondary umbels, SDWT: Seedling dry weight of tertiary umbels, SVIP: Seedling vigor index of primary umbels, SVIS: Seedling vigor index of secondary umbels, SVIT: Seedling vigor index of tertiary umbels

Table 5: Table of variable and fixed cost per treatment (740.52 square feet area)

Sr.No.	Fixed cost per treatment (Rs) (FC)		Variable cost per treatment (Rs)(VC)	
1.	Land preparation	340	Carrot seed	54
2.	Irrigation	340	Coriander seed	80
3.	Fertilizer	152	Turnip seed	50
4.	Herbicides	34	Radish seed	100
5.	Labor	425	Onion seed	150
6.	Land value	849		
7.	Abiana	2		
	Total fixed cost	2142		

Minimum seedling vigor index was calculated for carrot seed crop intercropped with turnip (340.5) (Table 4). The maximum secondary umbel seedling vigor index was calculated for sole carrot seed crop (504.0) and carrot seed crop intercropped with radish (440.8) were statistically not similar to each other but at par with carrot seed crop intercropped with onion (465.9) and coriander (457.0). The minimum seedling vigor index calculated for carrot seed crop intercropped with turnip (375.4) was statistically different from all other treatments (Table 4). The maximum tertiary umbel seedling vigor index was calculated for sole carrot seed crop (431.2), carrot seed crop intercropped with radish (416.9) and coriander (410.4) were statistically similar to each other and at par with carrot seed crop intercropped with and onion (371.8). The minimum seedling vigor index calculated for carrot seed crop intercropped with turnip (325.0) was also statistically at par with carrot seed crop intercropped with onion (Table 4).

Benefit Cost Ratio

Benefit cost ratio is a ratio between the output obtained from an activity and total cost that have been use to perform that activity (Mehmood et al., 2011). There was computing different costs by using economical methodology and the results obtained at the end of calculation (Table 5, Table 6, Table 7, Table 8) included fixed cost i.e. land preparation, fertilizer, irrigation, herbicide, labor, abiana and land value and variable cost i.e. seed of carrot, coriander, turnip, radish and onion was expressed the benefit cost ratio (Table 5). The benefit cost ratio for carrot and other vegetables intercropped with carrot seed crop was calculated separately (Table 8). The result obtained from that experiment expressed that the maximum benefit cost ratio obtained from carrot seed crop intercropped with turnip (2.10), carrot seed crop intercropped with onion (1.96), carrot seed crop intercropped with radish (1.85), carrot seed crop intercropped with coriander (1.55) and minimum benefit cost ratio was obtained from sole carrot seed crop (1.51). From our results we concluded that intercropping has positive affect on benefit cost ratio for all treatments.

4 | DISCUSSION

The research was conducted to find the impact of intercropping of carrot seed crop with other vegetables and it was exhibited that all used vegetable crops had noticeable effect on morphology and seed quality of carrot seed crop. Previously, an experiment was

Table 6: Table for total cost per treatment (740.52 square feet area)

Sr.No.	Treatments	Total fixed cost per treatment (Rs) (TFC)	Total variable cost per treatment (Rs) (TVC)	Total cost per treatment (Rs) (TFC + TVC)
1	Sole carrot seed crop	2142	54	2196
2	Carrot seed crop + Coriander	2142	134	2276
3	Carrot seed crop + Turnip	2142	104	2246
4	Carrot seed crop + Radish	2142	154	2296
5	Carrot seed crop + Onion	2142	204	2346

Table 7: Table for total outputs per treatment (740.52 square feet)

Sr.No.	Treatments	Carrot output per treatment (Rs)	Other vegetable output per treatment(Rs)	Total output per treatment(Rs)
1	Sole carrot seed crop	3324	0	3324
2	Carrot seed crop + Coriander	3096	450	3546
3	Carrot seed crop + Turnip	2350	2388	4738
4	Carrot seed crop + Radish	2815	1433	4248
5	Carrot seed crop + Onion	2666	1950	4616

Table 8: Table for benefit-cost ratio per treatment (740.52 square feet)

Sr.No.	Treatments	Total output per treatment (Rs)	Total cost per treatment (Rs)	Benefit cost ratio per treatment (BCR = total output/total cost)
1	Sole carrot seed crop	3324	2196	1.51
2	Carrot seed crop + Coriander	3546	2276	1.55
3	Carrot seed crop + Turnip	4738	2246	2.10
4	Carrot seed crop + Radish	4248	2296	1.85
5	Carrot seed crop + Onion	4616	2346	1.96

conducted on intercropping of bush bean with field and sweet maize and observed intercropping cause reduction in number of pods per plant of bush bean, which support our results of reduction in number of secondary umbels per plant of carrot seed crop when intercropped with different vegetables. It was also reported that the reduced seed yield of maize, and supported decreased seed weight of secondary umbels of carrot seed crop when intercropped (Santalla *et al*., 2001). An experiment was conducted on intercropping of pea with different winter vegetables and obtained the reduced 1000 seed weight of pea from intercropping (Qasim *et al*., 2013). A research was conducted on intercropping on maize and soybean and observed that there was reduced effect of intercropping on 1000 seed weight of soybean (Hayder *et al*., 2003). It was studied that the intercropping of carrot with cowpea vegetables and concluded that 100 seed weight of cowpea was reduced when intercropped (Da Costa *et al*., 2017). Intercropping of legumes with cereals in reference to reduce the infection of *Orobanche crenata* and concluded that there was no noticeable effect of intercropping on seedling fresh weight of legumes once the germination of seed take place. An experiment was performed on intercropping green manure crops-effects on rooting patterns and concluded that there was significant difference in seedling fresh and dry weight among all the treatments (Miyazawa *et al*., 2010). An experiment on intercropping of mung bean and rice was conducted and concluded that there was significant difference in seedling dry weight among all the treatments (Li *et al*., 2009). The vigor index of carrot seedling was measured and resulted that all order umbels gave the significant result for vigor index (Nagarajan *et al*., 2003; Singh *et al*., 2015). The research was conducted on intercropping of carrot and ground nut and observed an increase in benefit cost ratio of intercropping as compare to the sole crops that support our results as we obtained minimum benefit cost ratio from sole carrot seed crop and increased towards all treatments of intercrops (Hossain *et al*., 2006).

Conclusion

It was estimated that carrot seed crop intercropped with turnip showed maximum plant height with less number of secondary and tertiary umbels, minimum seed weight of primary, secondary and tertiary umbels, minimum 1000 seed weight of all order umbels, minimum seed weight per plant and per plot, minimum seedling length, fresh and dry weight and minimum vigor index for all order umbels. But instead of all these decreasing results turnip gave the maximum benefit cost ratio with more root yield. The sole carrot seed crop expressed the minimum height with maximum number of secondary and tertiary umbels, maximum weight of primary, secondary and tertiary umbels, maximum 1000 weight of all order umbels, maximum seed weight per plant, maximum seed weight per plot, maximum values for seedling length, fresh and dry weight and vigor index. But it has lowest benefit cost ratio. That showed that it was not much beneficial in reference to economical profit. From this experiment it was concluded that intercropping have positive effect on carrot seed production and turnip was

most recommended short duration vegetable for intercropping with carrot seed crop.

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