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Influence of Intercropping Patterns of Beet Leaf on Seed Yield, its Attributes and Economics of Onion Seed Crop

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ABSTRACT

The experiment was conducted during (October–June, 2018–19 and 2019–20) at CCS Haryana Agricultural University, Hisar in the Sub-tropical Northern plain of India with the aim to find a remunerative intercropping strategy for optimum onion seed production with green leaf cuttings of beet leaf. This investigation involved 17 intercropping arrangements as treatments, which exhibited cultivating multi-cut beet leaf crop with onion seed crop in different row arrangements (1 or 2 rows) and varied cutting frequency (3–6 cuttings) of beet leaf to understand its impact on onion seed yield and income generation. Onion seed crop (sole crop) recorded the highest benefit-cost ratio (3.37:1) with superior yield attributes namely, seed yield (581.2 kg ha^{-1}), seed stalk length (104 cm), seed stalk diameters (2.7 cm), seed stalk bulb^{-1} (10.3), seed weight umbel^{-1} (2.5 g). Among the intercropping treatments, Onion+Beet leaf (1 row) with 3 cuttings, recorded the highest onion seed yield (487.5 kg ha^{-1}) and benefit-cost ratio (2.76:1). In contrast, Onion seed crop+Beet leaf (2 rows) with 3 cuttings and left for beet leaf seed crop was performed poorly in all the parameters and recorded as the minimum value for seed yield (329.5 kg ha^{-1}), seed stalk length (85.5 cm), flower stalk diameter (1.9 cm), seed stalk bulb^{-1} (6.7) and B:C ratio (1.71). Therefore, the intercropping strategy of Onion+Beet leaf (1 row) with 3 cuttings can potentially raise the vegetable growers' income.

KEYWORDS: *Allium cepa*, *Beta vulgaris*, intercropping, seed production

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1. INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Alliaceae and the genus *Allium*, originated in Central Asia (Bagali et al., 2012), which is one of the most important monocotyledonous spices as well as vegetable crops grown for their pungent bulbs and flavourful leaves in the world (Welbaum, 2015). India is the second largest producer of onion bulbs after China, with an average productivity of 18.65 mt ha^{-1} (Anonymous, 2020). Maharashtra is the leading onion producing state, followed by Karnataka and Gujarat. The medicinal value of this spice crop is helpful for human beings, used as a traditional nutraceutical and medicinal plant, so it is a protective food (Singh and Khar, 2022). It is also preservative and rich in sulfur containing compounds that are responsible for their pungent odours and for many of their health promoting effects (Kumar et al., 2022). The demand for onion bulbs and their seeds is increasing with the ever-increasing population (Yeshiwas et al., 2023). Feeding a global population by 2050 is expected to become one of the greatest challenges of our time, and it will require an increase in food production (Anonymous, 2009). Moreover, the onion crop contributes to the commercialization of the rural economy and creates job opportunities for young people (Wondim and Geyo, 2024). Onion crop has two growth cycles: biennial for seed production and herbaceous annual for bulb production (Kavitha et al., 2018). Its propagation happens through seeds, so seed production is a prerequisite for its multiplication (Gupta and Singh, 2016). The best plant establishment and maximum output are dependent on the quality of the seed (Finch-Savage and Bassel, 2016). Therefore, to enable quick, impartial, and precise assessment of seed quality, different seed testing standards are required (Trivedi and Gunasekaran, 2013). The date of planting and plant spacing affect the growth characteristics, flowering, seed yield and quality parameters of onion crops (Kumar et al., 2015).

Beet leaf (*Beta vulgaris* var. bengalensis Hort.) is also known as Indian Palak, Beet leaf spinach or sag. It belongs to the family Chenopodiaceae native to the Indo-Chinese region (Khedkar et al., 2023). Beet leaf is grown for its nutritive leafy foliage, which is rich in vitamins with minerals and contains a high quantity of ascorbic acid and iron (Natesh et al., 2017). Leafy vegetables have a very high protective food value among all the vegetables called mines of minerals and are rich in vitamin A, vitamin C and minerals (Buturi et al., 2021). Due to its short height and quick-growing foliage, and multi-cut nature may it be suitable for intercropping (Singh et al., 2013). The Indian economy is predominantly rural and agricultural. However, the declining trend in the average size of landholding poses a serious challenge to the sustainability and profitability of farming (Touch et al., 2024). Under the gradual shrinking of land holdings, it is necessary to integrate land-based complementary enterprises on small farms that require less space, fewer external inputs, optimum resource utilization, and maximum returns (Babu et al., 2016). More natural resources can be used more effectively with intercropping patterns, which also benefits marginal and small farmers by providing ground cover for longer periods of time than mono-cropping (Bamboriya et al., 2022). The potential advantages of the cropping model include increase crop yield; improve soil fertility (Nyoki and Ndakidemi, 2018; Babu et al., 2022) and control soil erosion (Weisany et al., 2015). The seed yield plant^{-1} significantly improved in intercropping (Nitesh et al., 2021). The intercropping approach to vegetable production is of increasing importance and central interest to a large number of scientists in the field of agriculture and ecology (Brooker et al., 2015). Considering the aforementioned advantages of intercropping beet leaf with onion, this study was carried out to understand the influence of intercropping patterns of beet leaf on seed yield, its attributes and cost benefit ratio of onion seed crop.

2. MATERIALS AND METHODS

2.1. Experimental site and cultural practices

The field experiments were conducted during two *Rabi* seasons (October–June, 2018–19 and 2019–20) at the Research Farm, Department of Vegetable Science, CCS Haryana Agricultural University, Hisar (29° 10' N latitude, 75° 46' E longitude, 215.2 m above mean sea level). The experimental design was a randomized block design (RBD) with three replications for each treatment. The treatments involved intercropping beet leaf with onion seed crop (main crop) using different numbers of beet leaf rows (1 row and 2 rows) and varying cutting frequencies (3, 4, 5 and 6 cuttings). The experimental field was prepared by ploughing three times, followed by planking, levelling and raking to achieve a fine tilth. Onion bulbs were planted with a spacing of 60 cm between rows and 30 cm between bulbs within a row. Beet leaf crops were spaced at 15×5 cm^2 between rows and plants, respectively. In the intercropping treatments, beet leaf was sown in single-row and double-row patterns between onion plants, with variations in the number of cuttings followed by either uprooting or growing for seed. Thinning of the beet leaf seed crop was performed to maintain appropriate spacing in both sole and intercropping treatments. The first beet leaf cutting was done 35 days after sowing, with subsequent cuttings at 15–20 days interval. In all intercropping treatments, three common leaf cuttings of beet leaf were performed, after which some treatments were left for seed while others were uprooted. Onion umbels were harvested 3–4 times as they matured at different times in intercropping treatments. Harvesting was done when approximately 50% of the black seeds exposed to an umbel. The umbels were manually separated with a sickle and stored in gunny bags in their respective plots for sun drying. After complete sun drying, the crop was threshed manually and yield weighing was done using a digital electric balance. Various yield attributes and seed yield parameters for onion (intercrop's seed yield only) were recorded, along with net returns and the benefit-cost ratio of the cropping pattern. The data were averaged and analyzed for both years using statistical methods as per Gomez and Gomez (1984) with computations and analyses performed using a statistical program developed by O.P. Sheoran.

3. RESULTS AND DISCUSSION

3.1. Days to 50% bulb sprouting and 50% flowering of onion

The study revealed that intercropping with beet leaf did not significantly affect the days to 50% bulb sprouting, which ranged from 7.8 to 9.0 days. The days to 50% flowering ranged from 136.5 to 143.2 days. Intercropping extended the flowering period, with the shortest period (136.5 days) observed in T_1: Onion seed crop (sole crop). Among the intercropping, T_4: Onion+Beet leaf (1 row) 3 cuttings, had the shortest flowering time (137.5 days), followed by T_{11}: Onion+Beet leaf (2 rows) 3 cuttings (137.7 days). The delay in flowering in treatments such as T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop (143.2 days) could be attributed to shading or mulching effects (intercrop leaves) and competition for resources due to the presence of beet leaf left for seed after three cuttings (Table 1). These results contradict the findings of Patel et al. (2018), who observed no impact of intercropping on flowering time in soybean-maize combinations. In contrast, our results align with those of Chaudhary et al. (2018), who reported that crops flower in the minimum number of days when grown without mulch. Furthermore, Rabeschini et al. (2023) discovered that common beans produced earlier and more flowers when grown without neighboring plants, compared to when accompanied.

3.2. Length and diameter of the flower stalk

The maximum length (104.0 cm) and diameter (2.7 cm) of the flower stalk were observed in T_1: Onion seed crop (sole crop). Among intercropping treatments, T_4: Onion+Beet leaf (1 row) 3 cuttings had the highest values (101.3 cm length and 2.6 cm diameter) with T_{11}: Onion+Beet leaf (2 rows) 3 cuttings showing similar results (Table 1). The least values were recorded in T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop (85.5 cm length and 1.9 cm diameter) due to higher plant density and competition for nutrients, light and space. Similar results were reported in the onion by Amalfitano et al. (2019), who found that the number of flower stalks plant^{-1}, their height and diameter, and the inflorescence diameter decreased with the delay in bulb planting and the increase in density.

3.3. Onion seed stalks bulb^{-1}, seeds umbel^{-1} and seeds plant^{-1}

The sole onion crop T_1: Onion seed crop (sole crop) produced the maximum number of seed stalks bulb^{-1} (10.3) and seeds plant^{-1} (7008). Among intercropping treatments, T_4: Onion+Beet leaf (1 row) 3 cuttings had the highest number of seed stalks bulb^{-1} (9.6) and seeds plant^{-1} (6903), followed by T_{11}: Onion+Beet leaf (2 rows) 3 cuttings. Treatment T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop, had the minimum number of seed stalks (6.7) bulb^{-1} but the maximum seeds umbel^{-1} (894), indicating that the seed crop of beet leaf along with onion produced a greater number of seeds umbel^{-1} but did not improve yield traits (Table 1). Intercropping hindered the number of seed stalks plant^{-1} but enhanced the number of seed umbels^{-1}. Similar findings reported by Saini (2022) in Onion+Beet leaf intercropping combinations.

3.4. Onion seed yield umbel^{-1}, plant^{-1} and ha^{-1}

The maximum seed yield umbel^{-1} (2.5 g), plant^{-1} (26.2 g) and ha^{-1} (581.2 kg) were recorded in treatment T_1: Onion seed crop (sole crop). Among intercropping treatments, T_4: Onion+Beet leaf (1 row) 3 cuttings, yielded the highest (2.6 g umbel^{-1}, 24.4 g plant^{-1} and 487.5 kg ha^{-1}). The lowest yields (15.5 g plant^{-1} and 329.5 kg ha^{-1}) were observed in treatment, T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop (Table 2). The yield reduction in intercropping was consistent with findings by Saini et al. (2024). The superior yield in sole crops was attributed to reduced competition and better growing conditions reported by Bitew et al. (2021) in the finger millet+Legume intercropping. Overall, relay-cropped maize and soybean produced 94% and 69% of the sole cropping yield, as Feng et al. (2019) reported.

3.5. Leaf and seed yield of beet leaf (q ha^{-1})

The maximum leaf yield (41.27 t ha^{-1}) was recorded in the sole beet leaf crop treatment, T_3: Beet leaf 6 leaf cuttings (sole crop). Among intercropping treatments, T_{17}: Onion+Beet leaf (2 rows) 6 cuttings, had the highest leaf yield (25.05 t ha^{-1}) due to the higher number of leaf cuttings (6 cuttings) and the number of rows (2 rows). The minimum leaf yield (9.21 t ha^{-1}) was in T_5: Onion+Beet leaf (1 row) 3 cuttings and left for seed crop, with only three cuttings (Table 2). The maximum seed yield (1797 kg ha^{-1}) was recorded in the sole beet leaf crop treatment T_2: Beet leaf seed crop (sole crop), while T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop yielded the highest (1238 kg ha^{-1}) among intercropping treatments. These results were consistent with Panghal et al. (2021); Singh et al. (2018) discovered that the more cuttings though increased the total green leaf yield, but the seed yield and quality considerably reduced due to

Table 1: Effect of cropping patterns of beet leaf on phenological events and yield attributes of onion seed crop

Treatments	Days to 50% bulbs sprouting	Days to 50% flowering	No. of seed stalk bulb^{-1}	Length of flower stalk (cm)	Diameter of flower stalk (cm)	No. of seed umbels^{-1}	No. of seed plant^{-1}
T_1: Onion seed crop (sole crop)	8.5	136.5	10.3	104.0	2.7	679	7008
T_4: Onion+Beet leaf (1 row) 3 cuttings	8.8	137.5	9.6	101.3	2.6	726	6903
T_5: Onion+Beet leaf (1 row) 3 cuttings and left for seed crop	8.5	142.8	6.9	86.2	2.0	830	5688
T_6: Onion+Beet leaf (1 row) 4 cuttings	8.3	138.2	9.4	96.5	2.5	669	6262
T_7: Onion+Beet leaf (1 row) 4 cuttings and left for seed crop	8.5	142.2	7.2	86.9	2.1	811	5848
T_8: Onion+Beet leaf (1 row) 5 cuttings	8.7	139.0	9.0	94.3	2.4	655	5886
T_9: Onion+Beet leaf (1 row) 5 cuttings and left for seed crop	8.2	141.2	7.7	89.6	2.2	759	5840
T_{10}: Onion+Beet leaf (1 row) 6 cuttings	8.0	140.0	8.8	92.0	2.4	668	5834
T_{11}: Onion+Beet leaf (2 rows) 3 cuttings	7.8	137.7	9.4	98.4	2.6	684	6431
T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop	8.2	143.2	6.7	85.5	1.9	894	5930
T_{13}: Onion+Beet leaf (2 rows) 4 cuttings	7.8	138.7	9.2	94.8	2.5	657	6045
T_{14}: Onion+Beet leaf (2 rows) 4 cuttings and left for seed crop	8.5	142.5	7.1	86.9	2.1	827	5851
T_{15}: Onion+Beet leaf (2 rows) 5 cuttings	9.0	139.5	8.9	93.3	2.4	645	5728
T_{16}: Onion+Beet leaf (2 rows) 5 cuttings and left for seed crop	8.2	141.5	7.4	88.5	2.2	803	5921
T_{17}: Onion+Beet leaf (2 rows) 6 cuttings	8.3	140.8	8.6	91.2	2.3	693	5915
SEm±	0.4	0.4	0.2	1.3	0.0	31	201
CD (p=0.05)	NS	1.0	0.5	3.8	0.1	89	586

less absorption and storage of photosynthates. Narayan et al. (2018) reported that the highest seed yield of palak can be obtained by sowing in the second fortnight of October with two cuttings.

3.6. *Net returns and benefit-cost ratio (BCR)*

The highest net returns (₹ 408434 ha^{-1}) were from the treatment T_1: Onion seed crop (sole crop), attributed to the high seed yield. The highest net returns among intercropping treatments were in T_{11}: Onion+Beet leaf (2 rows) 3 cuttings (₹ 378118 ha^{-1}) due to additional earnings from beet leaf. The lowest net returns (₹ 40852 ha^{-1}) were from the sole beet leaf treatment T_2: Beet leaf seed crop (sole crop). The highest BCR (3.37) was recorded in T_1: Onion seed crop (sole crop), indicating the economic efficiency of growing sole onion for seeds (Table 2). The highest BCR among intercropping treatments was in T_4: Onion+Beet leaf (1 row) 3 cuttings (2.76). These results align with findings by Saini (2022), who reported that the seed production of onion in sole conditions produces a better yield, which fetches good returns and BC as compared to intercropping conditions.

3.7. *Weather parameters and cropping seasons*

Year to year variations in weather parameters could have

Table 2: Effect of cropping patterns of beet leaf on yield of main crop & intercrop, net returns and benefit cost ratio of the cropping system

Treatments	Onion seed wt. (g) umbel^{-1}	Onion seed wt. (g) plant^{-1}	Onion seed yield (kg ha^{-1})	Leaf yield of beet leaf (t ha^{-1})	Seed yield of beet leaf (kg ha^{-1})	Net returns	B:C ratio
T_1: Onion seed crop (sole crop)	2.5	26.2	581.2	-	-	408434	3.37
T_2: Beet leaf seed crop (sole crop)	-	-	-	-	1797	40852	1.30
T_3: Beet leaf 6 leaf cuttings (sole crop)	-	-	-	41.27	-	143692	1.77
T_4: Onion+Beet leaf (1 row) 3 cuttings	2.6	24.4	487.5	9.33	-	357926	2.76
T_5: Onion+Beet leaf (1 row) 3 cuttings and left for seed crop	2.3	15.7	341.1	9.21	929	188991	1.84
T_6: Onion+Beet leaf (1 row) 4 cuttings	2.3	21.5	474.2	11.99	-	341088	2.59
T_7: Onion+Beet leaf (1 row) 4 cuttings and left for seed crop	2.3	16.6	360.9	12.09	815	222493	1.95
T_8: Onion+Beet leaf (1 row) 5 cuttings	2.2	19.5	436.2	14.25	-	325111	2.45
T_9: Onion+Beet leaf (1 row) 5 cuttings and left for seed crop	2.2	17.1	388.1	14.31	579	256956	2.05
T_{10}: Onion+Beet leaf (1 row) 6 cuttings	2.1	18.3	415.5	15.45	-	307048	2.33
T_{11}: Onion+Beet leaf (2 rows) 3 cuttings	2.4	22.5	479.6	16.18	-	378118	2.64
T_{12}: Onion+Beet leaf (2 rows) 3 cuttings and left for seed crop	2.3	15.5	329.5	16.00	1238	190328	1.71
T_{13}: Onion+Beet leaf (2 rows) 4 cuttings	2.2	20.4	449.3	20.91	-	367323	2.48
T_{14}: Onion+Beet leaf (2 rows) 4 cuttings and left for seed crop	2.3	16.2	345.9	21.00	1176	228693	1.80
T_{15}: Onion+Beet leaf (2 rows) 5 cuttings	2.1	18.8	429.2	24.58	-	358468	2.35
T_{16}: Onion+Beet leaf (2 rows) 5 cuttings and left for seed crop	2.3	16.9	366.3	24.31	794	257458	1.85
T_{17}: Onion+Beet leaf (2 rows) 6 cuttings	2.1	17.8	403.7	25.05	-	319093	2.12
SEm±	0.1	0.3	2.8	-	17.0	-	-
CD (p=0.05)	0.2	1.0	8.3	-	54.0	-	-

Wt.: Weight; g: Grams; q: Quintal, ha: Hectare; B:C ratio: Benefit cost ratio

major impacts on crop yield. Fluctuations induced by weather conditions might alter management decisions, weeds, diseases, pests, and ultimately crop yield. Identifying the mechanisms leading to crop-yield volatility is not only fundamental for dampening fluctuations, it is also important in research on the attribution of loss and damage to climate change. The crop parameters obtained in the season 2019–20 were slightly higher than those of 2018–19. So that it is clear that the weather parameters interfered with crop growth, yield-attributing traits and the yield of the crop from season to season (Table 3).

Table 3: Monthly average weather data during the cropping years and average weekly weather data during the flowering of the onion seed crop

Month	Temperature (°C)		RH (%)		Bright sun shine (Hours)	Rainfall (mm)	Weeks of flowering in onion	Temperature (°C)		RH (%)		Bright sun shine (Hours)	Rain-fall (mm)
2018–19	Max	Min	M	E			2019	Max	Min	M	E		
October	32.7	16.9	84	38	6.6	0.0	11th week	24.9	9.1	91	48	6.1	0.0
November	27.9	11.7	90	46	4.2	0.0	12th week	28.9	11.8	80	42	7.2	0.0
December	21.9	4.9	93	50	4.9	0.0	13th week	32.6	13.5	81	28	7.3	0.0
January	19.2	5.2	94	60	4.6	13.8	14th week	36.0	16.0	74	28	8.0	7.3
February	20.4	8.0	93	59	4.6	8.8	15th week	36.9	20.0	69	27	7.0	0.0
March	26.5	10.5	87	42	6.8	6.0	16th week	32.9	17.2	81	37	7.2	8.2
April	36.7	18.4	69	27	7.8	15.5	17th week	40.7	20.6	56	19	8.5	0.0
May	39.0	21.6	59	26	8.8	59.8	-	-	-	-	-	-	-
June	40.5	25.8	68	33	8.3	105.1	-	-	-	-	-	-	-
2019–20							2020						
October	32.6	17.9	85	38	6.4	2.6	11th week	23.8	9.8	94	53	6.5	11.6
November	26.9	12.9	89	46	3.5	12.3	12th week	29.2	14.4	90	52	6.3	1.5
December	17.1	5.7	94	68	3.0	4.5	13th week	27.6	15.0	92	55	5.2	20.6
January	17.1	5.2	97	66	3.9	10.4	14th week	31.0	13.4	80	37	7.9	0.0
February	22.7	6.8	93	51	7.2	10.9	15th week	35.1	17.7	73	24	7.4	0.0
March	25.9	12.4	92	56	6.1	95.2	16th week	36.1	18.8	71	25	8.1	0.8
April	34.1	17.6	74	33	7.6	5.3	17th week	34.5	20.2	72	41	7.6	4.0
May	39.4	22.6	61	27	8.8	36.2	-	-	-	-	-	-	-
June	38.2	26.1	72	42	7.8	48.8	-	-	-	-	-	-	-

Max: maximum; Min: minimum; M: Morning; E: Evening: mm: Millimetres; RH: Relative humidity; °C: Degree celsius

4. CONCLUSION

The sole onion crop outperforms intercropping patterns in terms of seed yield and economic returns, attributed to reduced competition and optimal growing conditions. Sole onion crop is recommended as a beneficial approach for seed production.

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