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Shipra Thakur
Punjab Agricultural University, Ludhiana, Punjab, India

Viveka Katoch
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh, India

Aditya Barwal
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh, India

Sonali Parwan
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh, India

Monisha Thangavel
Punjab Agricultural University, Ludhiana, Punjab, India

Sakshi Suchita
Punjab Agricultural University, Ludhiana, Punjab, India

Corresponding Author:
Sakshi Suchita
Punjab Agricultural University, Ludhiana, Punjab, India

Optimizing fertility levels and spacing for enhanced nutritional quality in garden pea (*Pisum sativum* L) in the North-Western Himalayas

Shipra Thakur, Viveka Katoch, Aditya Barwal, Sonali Parwan, Monisha Thangavel and Sakshi Suchita

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Abstract
A field experiment was conducted during 2019-20 and 2020-21 at Vegetable farm of Department of vegetable science, CSKHPKV, Palampur, Himachal Pradesh, India to study the effect of different plant spacings and fertility levels on the quality parameters of powdery mildew resistant pyramid line of garden pea (*Pisum sativum* L.) line 1-2. The treatments included three plant spacings (30×10 cm, 45×10 cm, and 60×10 cm) and four fertility levels i.e. 100% recommended dose of fertilizers (RDF), 75% RDF, 125% RDF and 50% N through urea + 50% N through farmyard manure (FYM) + 100% PK. Results revealed that spacing did not significantly influence any of the quality traits across the years. However, fertility levels had a significant effect, with the integrated nutrient treatment recording the highest TSS (18.24 °Brix) and ascorbic acid content (21.92 mg/100 g), while 125% RDF gave the maximum crude protein content (20.90%). The standard check Azad Pea-1consistently showed the lowest values across all parameters. These findings underscore the importance of optimized nutrient management, particularly the integration of organic and inorganic sources in improving the nutritional quality of garden pea.

Keywords: Garden pea, spacing, TSS, ascorbic acid, crude protein

Introduction
Garden pea (*Pisum sativum* L.) is a major cool-season vegetable crop grown extensively for its immature green pods, which are consumed fresh, frozen, or processed (Tar'an *et al.* 2005) [1]. It is a rich source of high-quality protein, vitamin C, minerals, dietary fiber and carbohydrates, making it important in both urban and rural diets. Owing to its nutritional richness and plays an important role in sustainable farming systems by improving soil fertility by fixing atmospheric nitrogen into the soil (Rahman *et al.* 2018) [2]. With growing consumer awareness about nutrition and health, the demand for vegetables with superior quality traits is increasing, making nutrient management and agronomic optimization critical for both yield and quality enhancement.

Among the key biochemical constituents of garden pea, Total Soluble Solids (TSS) indicate the concentration of soluble sugars and contribute to taste and flavor; ascorbic acid (vitamin C) is a vital antioxidant that enhances the nutritional and functional value of the pods; and crude protein content is a major indicator of dietary quality. (Tiwari *et al.* 2020) [3] These quality attributes are influenced by a range of factors including genetic makeup, environmental conditions, and agronomic practices, particularly plant nutrition and spacing.

Fertility management is a crucial determinant of vegetable quality, as it affects nutrient uptake, plant metabolism, and biosynthesis of primary and secondary metabolites. The balanced application of nitrogen (N), phosphorus (P), and potassium (K) is essential for plant growth and biochemical synthesis [4]. However, excessive reliance on chemical fertilizers may lead to nutrient imbalances, soil degradation, and environmental concerns (Bobade *et al.* 1992) [5] (Kumari *et al.* 2017) [6]. In this context, the integration of organic sources such as farmyard manure (FYM) with inorganic fertilizers is gaining importance as a sustainable strategy to enhance nutrient availability and crop quality while improving soil health. Such integrated nutrient management (INM) approaches have shown promise in legumes for improving both yield and quality. (Sepehya *et al.* 2015) [7]

Plant spacing is another key agronomic factor that influences plant architecture, light interception, air circulation, and resource competition (Gautam *et al.* 2008) [8]. Closer spacing often increases plant population per unit area but may lead to interplant competition, while wider spacing can improve individual plant performance but reduce total productivity.

Despite numerous studies on the influence of nutrient management and spacing on yield, limited information is available on their combined or individual effects on quality traits in garden pea. Furthermore, such studies are scarce for promising breeding lines like garden pea line 1-2, which exhibit desirable agronomic and market traits.

In light of this, the present investigation was undertaken to evaluate the effect of varying fertility levels and plant spacings on the TSS, ascorbic acid, and crude protein content of powdery mildew resistant pyramid line of garden pea line 1-2 over two consecutive rabi seasons. The objective was to determine the most suitable fertility regime and plant spacing that optimize the nutritional quality of the crop without compromising sustainability.

Materials and Methods

Field experiment comprising of 12 treatments was conducted in Randomized Block Design with three replications during *rabi* season of 2019-20 and 2020-21 at Vegetable Research Farm, Department of Vegetable Science and Floriculture, CSK HPKV, Palampur to evaluate the performance of pea Line 1-2 with four fertility levels viz., recommended dose (25:60:60 kg N:P_2O_5:K_2O/ha) of NPK (100%), 75% of recommended NPK, 125% of recommended NPK and 100% PK and at three different spacings *viz*., 30×10cm, 45×10cm and 60×10cm with Azad Pea-1 as standard check. Line 1-2 was derieved from the the cross BC_3F_2 (Lincoln/JI1559)// BC_3F_2 (Lincoln/JI2480).

Standard check : Azad Pea-1 + 100% recommended dose of NPK at 45×10 cm.

The recommended dose of fertilizer is 25:60:60 kg N: P_2O_5:K_2O/ha, respectively.

Plot size: 1.5 m × 1.8 m = 2.7m^2

Total soluble solids (^{0}Brix)

Seeds of fresh pods from second picking were crushed in pestle-mortar and the liquid extract obtained was used to record the total soluble solids with the help of ERMA hand refractrometer in ^{o}Brix.

Ascorbic acid content (mg/100 g fresh weight basis)

Ascorbic acid content was estimated at marketable green fruit stage by '2, 6-dichlorophenol-indophenol Visual Titration Method' as described by Ranganna, 1979 [9].

Crude protein content (%)

Fresh pea seeds were dried in hot air oven at 50 ^{0}C for 12 hours and then grounded to a fine powder. Nitrogen content in this sample was estimated by Microkjeldahl method (Jackson, 1973) [10]. The crude protein content was calculated as:

Crude protein content (%) = Estimated nitrogen × 6.25

Statistical analysis

The data obtained on various aspects in the present study were subjected to statistical analysis using randomized block design as per procedure suggested by Gomez and Gomez 1982 [11]. The treatment effects were compared at 5% level of significance, wherever, the effects exhibited significance at 5% of probability, the critical difference (CD) was calculated.

Results and Discussion

The performance of any crop depends on the interaction between genetic and environmental factors. The environment plays an important role in influencing growth, development and ultimately the yield of a crop. Among the various environmental factors, weather parameters *viz*. ambient temperature, rainfall, sunshine duration and relative humidity play an important role.

The weather data during crop growing season from 6th November 2019 to 30th April 2020 depicted in Fig. 1 and appended in Appendix-I revealed that the weekly maximum and minimum temperature ranged between 13.07 to 31.34 ^{0}C and 1.50 to 16.50 ^{0}C, respectively. The crop received well distributed rainfall of 640.83 mm. The highest weekly rainfall of 107.80 mm was received during standard meteorological week 11. The average relative humidity and sunshine hours ranged from 43.50% to 80.64% and 2.21 to 8.93 hours/day, respectively during the season. Similarly, the weather data during 6th November to 30th April 2020-21 depicted in Fig. 2 and appended in Appendix-II revealed that the weekly maximum and minimum temperature ranged between 14.86 to 27.29 ^{0}C and 0.83 to 13.79 ^{0}C, respectively during ontogeny of the crop. The crop received well distributed rainfall of 313.6 mm during the crop season. The highest weekly rainfall of 68.60 mm was received during standard meteorological week 16. The average relative humidity and sunshine hours ranged from 39.71 to 71.21% and 2.79 to 9.29 hours/day, respectively during the season. Perusal of weather data indicated that the overall weather conditions during the year 2019-20 were found to be favourable for growth and development of garden pea over years.

The data presented in Table 1 revealed that different spacings had no influence on total soluble solids, ascorbic acid content and protein content during 2019-20, 2020-21 and on pooled basis. Non significant effect of spacing on TSS and protein content was also observed by Attar *et al.* 2013 [12]. However, among the spacings highest total soluble solids (18.06, 17.58 and 17.82 ^{0}brix) were observed at 60×10cm followed by 45×10cm (17.75, 17.53 and 17.63 ^{0}brix) and 30×10cm (17.73, 17.50 and 17.63 ^{0}brix). significantly higher total soluble solids at wider spacing were found by Batra *et al.* 1992 [13]. The scrutiny of data presented in Table 4.15 also showed that the fertility levels had significant influence on total soluble content of garden pea and revealed that maximum TSS content (18.32, 18.17 and 18.24 ^{0}brix) was found in 50% N through FYM + 50% N through urea + 100% PK followed by 100% (17.87, 17.43 and 17.65 ^{0}brix) fertility level which was found to be at par with 125% fertility level (17.80, 17.41 and 17.61 ^{0}brix) over the years and on the pooled basis. Significant increase in total soluble solids content with application of different organic manures and fertilizer doses were recorded by Sepehya *et al.* [7]. Lowest total soluble solids content (17.40, 17.13 and 17.27 ^{0}brix) was found in application of 75% of recommended dose of fertilizer. The interaction effects of spacing and fertility levels for this character was found to be

non-significant for both the years and on the pooled basis. The overall performance of the line was found significantly different from the standard check Azad Pea-1 over both the years and on the pooled basis.

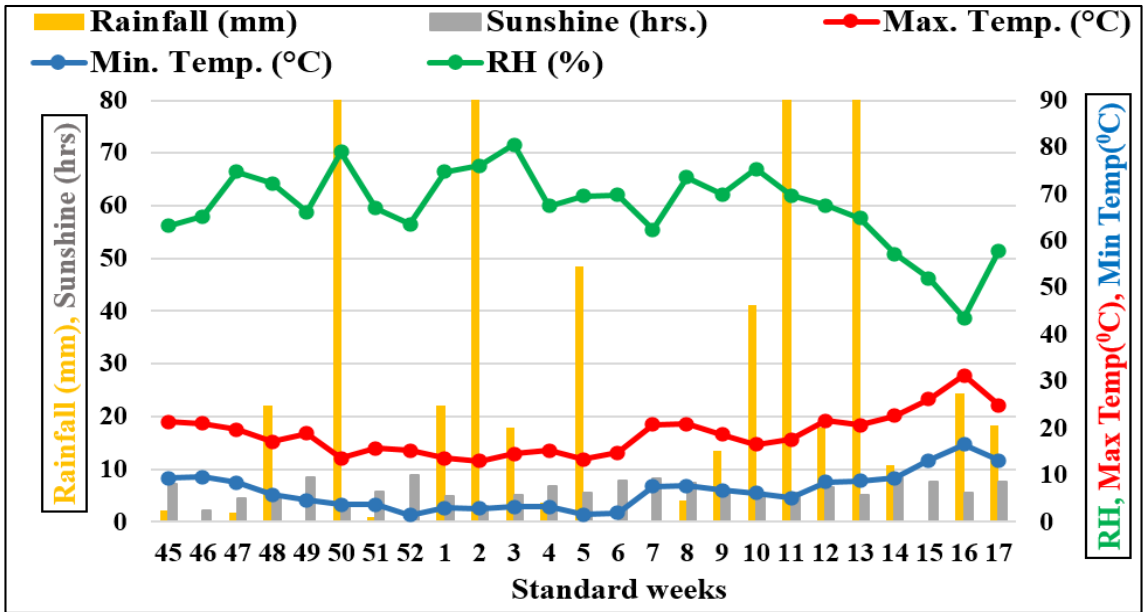

Fig 1: Mean weekly weather condition during the cropping season *rabi* 2019-20

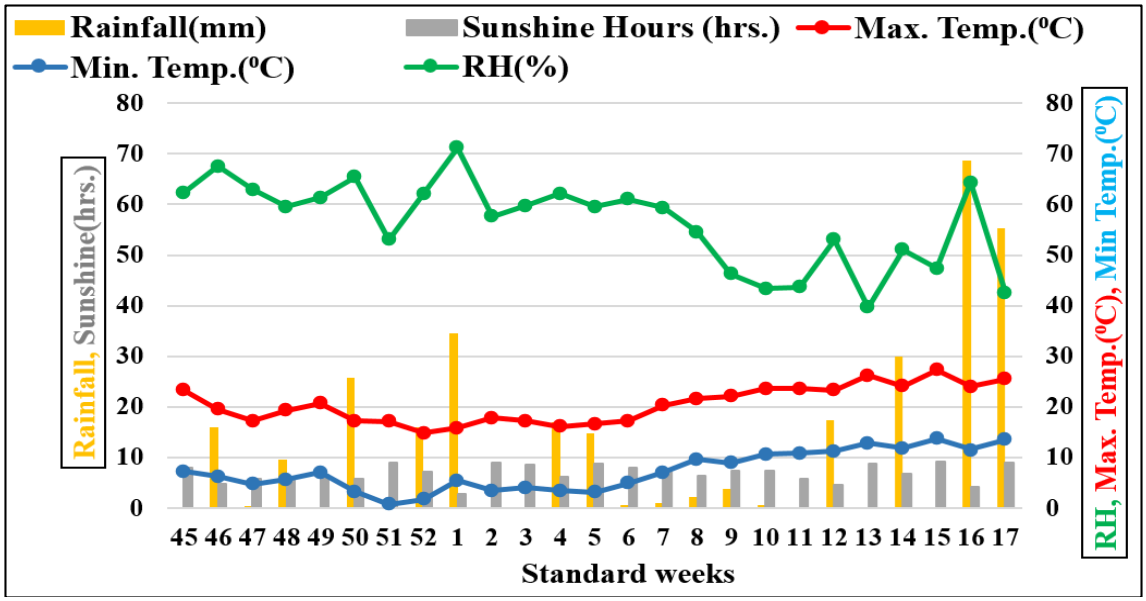

Fig 2/; Mean weekly weather condition during the cropping season *rabi* 2020-21

Different fertility levels showed significant influence on the ascorbic acid content of the garden pea during 2019-20, 2020-21 and on the pooled basis. Highest ascorbic acid content (22.17, 21.67 and 21.92 mg) was recorded in 50% N through urea + 50% N through FYM + 100% PK which was found to be at par with 125% (21.90, 21.40 and 21.65 mg) and 100% (21.87, 21.37 and 21.62 mg) fertility levels and minimum ascorbic acid content (20.73, 20.23 and 20.48 mg) was found in application of 75% of recommended dose of fertilizer, over the years and on the pooled basis. The overall effect of the Line, 1-2 was found to be non-significant to the standard check for ascorbic acid content.

Amongst the fertility levels, significant influence was recorded over the years and on pooled basis for the protein content. Maximum protein content (21.13, 20.67 and 20.90%) was found in 125% fertility levels which was found to be at par with application of 50% N through urea + 50% N through FYM + 100% PK (20.27 and 20.50%) during the year 2020-21 and on the pooled basis. High protein content at 125% fertility level may be attributed to the more availability of nitrogen during the development stage of plant which increased the nitrogen content of the cell sap in the form of protein, amides and aminoacids which might have resulted in the increased protein content of the seeds. During 2019-20 it was found to be significantly different from other fertility levels. Lowest protein content (20.50, 20.01 and 20.26%) was found in 75% fertility during both the years and on the pooled basis.

The interaction effect of spacing and fertility levels was found to be non-significant for TSS, ascorbic acid content and protein content over the years and on the pooled basis. Contrary to the present findings, significant interactions between spacing and fertility levels for total soluble solids and protein content were observed by Kalabandi *et al.* 2017

[14]. The overall performance of the line was found to be significantly different for the quality parameters except ascorbic acid content from the standard check Azad Pea-1.

The data presented in Table 4.15 revealed that spacing had no effect on quality traits but fertility levels had significant effect quality traits. TSS and ascorbic acid content were maximum with and application of 50% N through urea + 50% N through FYM + 100% PK. Maximum protein content was observed in125% fertility level.

Table 1: Effect of different spacing and fertility levels on TSS and Ascorbic acid and crude protein content of garden pea, Line 1-2 during 2019-20, 2020-21 and on the pooled basis

Treatment	TSS (^{0}brix)			Ascorbic acid (mg/100 g)			Crude protein (%)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Spacing (S)									
30×10cm	17.73	17.50	17.63	21.67	21.17	21.42	20.76	20.29	20.53
45×10cm	17.75	17.53	17.63	21.67	21.17	21.42	20.76	20.29	20.53
60×10cm	18.06	17.58	17.82	21.67	21.17	21.42	20.76	20.28	20.52
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility levels (F)									
100% recommended dose of fertilizer	17.87	17.43	17.65	21.87	21.37	21.62	20.67	20.20	20.43
75% recommended dose of fertilizer	17.40	17.13	17.27	20.73	20.23	20.48	20.50	20.01	20.26
125% recommended dose of fertilizer	17.80	17.41	17.61	21.90	21.40	21.65	21.13	20.67	20.90
50% N through urea + 50% N through FYM + 100% PK	18.32	18.17	18.24	22.17	21.67	21.92	20.73	20.27	20.50
CD (P=0.05)	0.42	0.35	0.24	0.55	0.61	0.57	0.36	0.45	0.37
S×F	NS	NS	NS	NS	NS	NS	NS	NS	NS
Check vs others									
Check	16.97	16.57	16.77	21.57	21.07	21.32	19.33	18.87	19.10
Others	17.85	17.54	17.69	21.67	21.17	21.42	20.76	20.29	20.52
CD(P=0.05)	0.54	0.45	0.30	NS	NS	NS	0.46	0.57	0.47

Conclusion

Fertility levels significantly influenced the quality parameters of garden pea line 1-2, while plant spacing had no notable effect. The integrated nutrient treatment (50% N through urea + 50% N through FYM + 100% PK) enhanced TSS and ascorbic acid content, whereas 125% RDF recorded the highest crude protein content. These results highlight the importance of integrated and balanced nutrient management for improving the nutritional quality of garden pea.

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