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Influence of varieties and fertilizer doses on growth, yield, quality and profitability of carrot (*Daucus carota* L.)

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Abstract
A field experiment was conducted during *Rabi* season, 2021-22 Experimental Farm of the Department of Vegetable Science, College of Horticulture, Mandsaur (M.P.) The experiment comprised of two carrot varieties (V_1- Pusa Rudhira and V_2 - Pusa Kesar) and five fertility levels (F_0 – 0 kg/ha, F_1 – NPK 40:30:30 kg/ha, F_2 – NPK 60:40:40 kg/ha, F_3 -NPK 80:50:50 kg/ha, F_4 – NPK 100:60:60 kg/ha). All together 10 treatment combinations were laid out in Factorial Randomized Block Design with three replications. Variety V_1- (Pusa Rudhira) exhibited maximum plant height (37.35 cm), number of leaves per plant (13.99), fresh weight of plant (257.31 g) and dry weight of plant (21.54 g). Earliest days to harvest (96.13), root length (27.88 cm), root diameter (3.94 cm), fresh weight of root (94.12 g), and root yield per hactare (313.74 q/ha), were observed with variety V_1 (Pusa Rudhira). Under quality parameters highest fiber content (964.41 mg/100 g), specific gravity (1.04 g/cc) and T.S.S. (8.74 ^{0}Brix) in root were also found in case of variety V_1 (Pusa Rudhira). Among fertility levels, application of F_3 (NPK 80:50:50 kg/ha) showed maximum growth, yield and quality parameters with all the two varieties of carrot. The net income and B:C ratio i. e. 105886.85 and 2.07 was found to be superior with variety V_1 (Pusa Rudhira) and fertility level F_3 (NPK 80:50:50 kg/ha).

Keywords: Carrot, fertility levels, NPK, yield, fiber content, TSS, B:C ratio

Introduction
The carrot (*Daucus carota* L.) is originated in Asia. Carrot belongs to the family Umbelliferae, genus Daucus and species carota with chromosome no 2 n = 18. The carrot is an annual for root production and biennial for seed production. The inflorescence of carrot is 'Compound Umbel' and the edible part of carrot is modified root (Conical form) which develops in soil (Pal *et al*., 2019) [19].

Nutrient composition of carrot root is moisture 86 %, protein 0.9 g, carbohydrate 10.6 g, fat 0.2 g, fiber 1.2 g, energy 48 kilo calorie, mineral 1.1 g, iron 2.2 mg, carotene 1890 mg, thiamine 0.04 mg, riboflavin 0.02 mg, niacin 0.5 mg, vitamin-C 3 mg, folic acid 15 mg, calcium 80 mg and phosphorus 30 mg per 100 g of edible portion (Bose *et al*., 2003) [3]. Carrot is one of the important and major root vegetable used as salad and cooked vegetable, canned pickles, preserves, sweets (especially Gajar halwa), carrot powders, kanji an appetizing drink *etc*. Besides being food, carrot has therapeutic importance as it enhances resistance against blood and eye diseases (Kumawat *et al*., 2018) [13].

A number of factors are responsible for successful cultivation of high quality roots, among these the judicious application of fertilizers is one of the important factors. Fertilization plays an important role in crop production because it affects crop quantity and quality, as well as physical, biological, and physiochemical properties of soil, and the quality of ground and surface water, as well as the air. From the producer's point of view, fertilization is an important factor impacting production costs (Sikora *et al*., 2020) [25].

Nitrogen is one of the most important yield-limiting nutrients for plants. Nitrate accumulation is affected not only by the type of nitrate fertilizer used, but also by nitrogen rates, variety, environment, harvesting date and other agronomical factors (Boskovic-Rakocevic *et al*., 2012) [4]. Phosphorus helps in nutrients uptake by promoting root growth and thereby increases in total dry matter. The phosphorus requirements vary depending upon the nutrient content of the soil. Phosphorus deficiency results in poor root development and subsequently reduces yield (Nahar *et al*., 2014) [16].

Potassium is necessary for the translocation of sugars and formation of carbohydrates. Potassium also provides resistance against pest and diseases and drought as well as frost stresses.

It is a highly mobile element in the plant and has a specific phenomenon; it is called luxury consumption (El-Nasar and Ibrahim, 2011) [9].

Materials and Methods

The field experiment was conducted at Research Field of the Department of Vegetable Science, College of Horticulture, Mandsaur, Madhya Pradesh during *Rabi* season, 2021-22. Mandsaur is situated in Malwa plateau in western part of Madhya Pradesh at north between latitude of 23045' to 24013' north and longitude of 74044' to 75018' East at an altitude of 435.20 m above mean sea level. The topography of the experimental field is plain. The soil of the experimental field was light alluvial soil having sandy loam texture with uniform topography. The treatments consisted of two carrot varieties (V_1- Pusa Rudhira and V_2 - Pusa Kesar) and five fertility levels (F_0 – 0 kg/ha, F_1 – NPK 40:30:30 kg/ha, F_2 – NPK 60:40:40 kg/ha, F_3 – NPK 80:50:50 kg/ha, F_4 – NPK 100:60:60 kg/ha).

The experiment was laid out in a factorial randomized block design with ten treatment combinations each replicated three times. Entire quantity of P and K and half dose of N as per treatment was applied in the form of DAP, MOP and Urea, respectively before sowing at the time of field preparation. Whereas the remaining dose of nitrogen was given by top dressing after 30 days of sowing. The soil samples were collected before and after the experimentation and analyzed. The plots were irrigated regularly at day before noon or late in the evening to keep the soil moderately moist. All the standard agronomic practices were followed. The observations on plant growth, yield and quality components were recorded for the net plot. Five plants were randomly selected from each plot and tagged. The observations were taken on growth, yield and quality parameters.

Results and Discussion

Growth attributes

Maximum plant height was noted significant with the variety V_1 (Pusa Rudhira) as compared to the variety V_2 (Pusa Kesar). This might be due to genetic attributes of these varieties. The augmentation in plant height is the result of intensive cell division and cell enlargement which in turn is influenced by protein synthesis. Therefore any variation in cell metabolism can consequently affect the plant height (Sharma *et al*., 2020) [23]. Fertilizer dose F_3 (NPK- 80:50:50 kg/ha) had exhibited maximum plant height at 30, 45 and 60 DAS, while minimum plant height was observed in case of fertilizer dose F_0 (NPK- 0 kg/ha). It was observed that an increase in nitrogen levels positively affected the plant height which might be due to the role of nitrogen for cell division, cell enlargement and protein synthesis characteristics (Kumar *et al*., 2022) [12]. These findings are in agreement with the findings of El-Tohamy *et al*. (2011) [10].

Number of leaves per plant varied significantly between both the carrot varieties. Variety V_1 (Pusa Rudhira) exhibited significantly more number of leaves per plant when compared to variety V_2 (Pusa Kesar) at 30, 45 and 60 DAS. The difference in number of leaves among varieties was probably due to the rate of leaf initiation which would be an inherent character of the varieties (Kushwah *et al*., 2019) [14]. Similar findings have been reported by Ali *et al.* (2006) [1], Shoma *et al.* (2014) [24] in carrot. While the highest number of leaves per plant were counted from fertilizer dose F_3 (NPK- 80:50:50 kg/ha) and the lowest was obtained from fertilizer dose F_0 (NPK- 0 kg/ha). The production of maximum number of leaves in plant might be due to the fact of application of sufficient quantities of nitrogen nutrient that resulted in increase in vegetative growth as compared to control where no any essential nutrients were applied. Carrot requires higher amount nitrogen together with adequate phosphorus and potassium for production of maximum number of healthy leaves. Similar findings have been reported by Wilson *et al.* (2009) [29].

Variety V_1 (Pusa Rudhira) was recorded the maximum fresh weight of plant at the harvesting stage. The minimum fresh weight of the plant was recorded in case of variety V_2 (Pusa Kesar) at the harvesting stage. Higher plant height and number of leaves might have resulted in more photosynthesis and accumulation of food material in V_1 (Pusa Rudhira) resulting in higher fresh weight of plant. Similar result is found in Kushwah *et al*. (2019) [14]. Whereas the fresh weight of plant was significantly influenced by fertilizer doses. The highest fresh weight of the plant was observed with fertilizer dose F_3 (NPK- 80:50:50 kg/ha) at the harvesting stage. Lowest fresh weight of plant was found under the fertilizer dose F_0 (NPK- 0 kg/ha). Similar results have been quoted by Baloch *et al.* (2014) [2] and Kumawat *et al.* (2018) [13] in carrot.

The observations showed that varieties had a significant influence on the dry weight of the plant (g) after harvesting. The variety V_1 (Pusa Rudhira) had the maximum dry weight of plant, whereas the minimum dry weight of the plant was observed in case of variety V_2 (Pusa Kesar) at the harvesting stage. This might be due to more number of leaves and higher leaf length enhances the photosynthesis, accumulation of photosynthates consequently in higher dry weight of plant (Kushwah *et al*. (2019) [14]. The maximum dry weight of plant was registered with fertilizer dose F_3 (NPK- 80:50:50 kg/ha), while minimum dry weight of plant was recorded with fertilizer dose F_0 (NPK- 0 kg/ha) after harvesting. The increase in fresh and dry weight of root could be due to higher uptake and accumulation of greater amount of photosynthates leading to increase in number of leaves, plant size and fresh bio mass, which in turn yields higher dry matter, content (Satari *et al*., 2020) [22].

Effect of varieties with respect to day to harvest was found significant. Earliest variety for days to harvest was V_2 (Pusa Kesar). Maximum day to harvest were recorded with variety V_1 (Pusa Rudhira). The differences in maturity period can be attributed to genetic differences among the cultivars and ecological as well as climatic condition, as climate during growth and development of plant plays a dominant role in growth, yield and quality (Dongarwar *et al*., 2017) [7]. The results are in line with results of Singh *et al.* (2018) [26] and Sharma *et al.* (2020 [23] in carrot. Among different fertilizer doses, maximum days to harvest were recorded with F_0 (NPK- 0 kg/ha) and minimum days to harvest were recorded under fertilizer dose F_3 (NPK- 80:50:50 kg/ha). The early harvesting might be due to positive action of supplied NPK on physiological regulation of root formation in the plant which reduces the timing of Harvesting (Kumar *et al*., 2022) [12].

Yield attributes

The longest root was produced by variety V_1 (Pusa Rudhira) as compared to minimum root length was obtained under variety V_2 (Pusa Kesar). Environmental and genetic factors strongly effect on root length. So cultivars with more number of leaves have more root length. Similarly soil conditions might have an effect on root length. So, different cultivars have different root length according to their behaviour

(Pervez *et al*., 2003) [21]. Similar findings were reported by Pandey and Sharma (2017) [20]. The length of root of carrot was significantly influenced by the application of fertilizer doses. Maximum length of root was produced from fertilizer dose F_3 (NPK- 80:50:50 kg/ha) It was observed minimum length of root with fertilizer dose of F_0 (NPK- 0 kg/ha). This might be due to the affect that increased NPK levels, helped in expansion of leaf area and chlorophyll content which coupled with increased net photosynthetic rates and in turn increased the supply of carbohydrates to plants. The application of NPK favoured the metabolic and auxin activities in plant and ultimately resulted in increased root length (Kumawat *et al*., 2018) [13].

The highest root diameter was recorded in variety V_1 (Pusa Rudhira) and the lowest diameter of root per plant was recorded in variety V_2 (Pusa Kesar). This showed that these differences might be due to genetic composition in the expression of growth potentials. The similar variations in diameter of root among different varieties have reported by Shoma *et al.* (2014) [24] and Nikmatullah *et al.* (2021) [18]. The root diameter had exerted significant influence by fertilizer doses. The highest root diameter resulted from fertilizer dose F_3 (NPK- 80:50:50 kg/ha) However lowest diameter of root was observed under fertilizer dose F_0 (NPK- 0 kg/ha). In general the treatment having produced taller plant height and higher number of leaf per plant had higher root diameter. It might be due to increased photosynthesis in those treatments which resulted in higher food production and storage of produced food in storage roots (Ali *et al*., 2006) [1]. These findings are in agreement with those reported by Nahar *et al*. (2014) [16].

Variety V_1 (Pusa Rudhira) registered highest fresh weight of root. Minimum fresh weight of root was found under variety V_2 (Pusa Kesar). Higher root length, root girth and diameter of root might have resulted in higher fresh weight of root. Nutrient level indicated significant effect on fresh weight of root (Kushwah *et al*., 2019) [14]. Result gives an impression that fertilizer doses played a significant positive role on fresh weight of root of carrot. The highest average fresh weight of root of carrot was found from the fertilizer dose F_3 (NPK- 80:50:50 kg/ha) However lowest fresh weight of root (g) was obtained from fertilizer dose F_0 (NPK- 0 kg/ha). The increase in yield attributes might be due to nitrogen which is a component of chlorophyll probably enhanced photosynthesis and contributed to the accumulation of photosynthates in the roots, hence, the increase in root weight (Dawuda *et al*., 2019) [5]. The effect of K on rate of photosynthesis as well as transport of the photosynthetic product from the leaves to the storage root (El-Nasar *et al*., 2011) [9].

The maximum root yield recorded with variety V_1 (Pusa Rudhira) while variety V_2 (Pusa Kesar) was recorded the minimum root yield of carrot. The root yield per hectare is a result of translocation of more quantum of carbohydrates from the source to sink. As the varieties which have shown superior performance in yield have significantly more number of vigorous leaves on it and more plant height, which could have synthesized more food material and supplied to the roots, that might have resulted in increasing the weight and diameter of roots and ultimately resulted in getting higher root yield (Ladumor *et al*., 2020) [15]. The significantly highest root yield was obtained by applying fertilizer dose F_3 (NPK- 80:50:50 kg/ha) while the lowest root yield was obtained from fertilizer dose F_0 (NPK- 0 kg/ha). Nitrogen which is a component of chlorophyll probably enhanced photosynthesis and contributed to the accumulation of photosynthates in the roots, hence, the increase in root weight and yield (Dawuda *et al*., 2019) [5].

Quality attributes

The recorded observation revealed maximum fiber content with variety V_2 (Pusa Kesar) as compared to variety V_1 (Pusa Rudhira) which observed minimum fiber content. This might be due to the genetic makeup of particular variety and probably could be the result of favorable agro climatic conditions available during the growth period (Dongarwar *et al*., 2018) [8] in radish. Similer results were reported by Nargave *et al*. (2018) [17] in radish. Effect of different fertilizer doses had exerted significant effect on fiber content of carrot. Higher fiber content was observed with F_3 (NPK- 80:50:50 kg/ha) while the fertilizer dose F_0 (NPK- 0 kg/ha) was observed minimum fiber content.

Varieties had exerted significant influence on specific gravity (g/cc) of roots of carrot. Variety V_1 (Pusa Rudhira) was recorded maximum value of specific gravity while the minimum value of specific gravity was observed with V_2 (Pusa Kesar) in carrot. The variation in specific gravity was found due to genetically difference among the varieties. These results are in line with Ladumor *et al.* (2020) [15] in carrot. Different doses of fertilizer had a considerable influence on specific gravity (g/cc). The maximum specific gravity of the carrot was tested with the fertilizer dose F_3 (NPK- 80:50:50 kg/ha). The fertilizer dose treatment F_0 (NPK- 0 kg/ha) resulted in the minimum specific gravity after the harvesting stage. This might be due to increase in the root volume of carrot because of optimum levels of NPK dose, which helped in better assimilation of carbohydrates and build-up of new cells and consequently there was increased size of the root in turn more root volume as the root volume is mainly depends on the size or weight of the root. These findings are in close association with the report of Hailu *et al.* (2008) [11] in carrot.

Result indicated that varieties showed significant impact on total soluble solid (^{0}Brix). Highest value for total soluble solids was recorded in case of variety V_1 (Pusa Rudhira). The minimum value of total soluble solid was observed in the variety V_2 (Pusa Kesar). The variation in total soluble solids might be due to genetic make-up of varieties. Such kind of genetic variations for quality characters had also reported by Kushwah *et al.* (2019) [14] and Singh *et al.* (2020) [27] in carrot. The application of fertilizer dose treatment exhibited significant influence on total soluble solid (^{0}Brix). Maximum total soluble solids (^{0}Brix) was reported with fertilizer dose F_3 (NPK- 80:50:50 kg/ha), while minimum total soluble solids was recorded by fertilizer dose F_0 (NPK- 0 kg/ha). It might be due to accumulation of more reserve substances in root (Kumar *et al*., 2022) [12]. K played a key role in increasing the root TSS value (El-Tohamy *et al*., 2011) [10]. Potassium has a prominent role in translocation of photo assimilates, sugars and other soluble solids which are responsible for increased TSS (Subba *et al*., 2016) [28].

Economic of the treatments

The significantly highest gross, net income and B:C ratio were observed with variety V_1 (Pusa Rudhira), while variety V_2 (Pusa Kesar) was found minimum gross income, net income and B:C ratio in carrot. Higher yield, long sized roots and earliness are some of the character which might be responsible for increase in profit (Sharma *et al*., 2020) [23]. Similar results have been reported by Kushwah *et al.* (2019) [14] in carrot. Fertilizer doses revealed significant effect on gross income, net income and B:C ratio. Highest gross

income, net income and B:C ratio were noted in fertilizer dose F_3 (NPK- 80:50:50 kg/ha) while the minimum gross income, net income and B:C ratio were observed in fertilizer dose F_0 (NPK- 0 kg/ha). Similar results have been reported by Dawuda *et al.* (2011) [6] in carrot. Maximum gross income, net income and B:C ratio were observed with the treatment combination V_1F_3.

Table 1: Effect of varieties and varieties and fertilizer doses on growth

Treatment	Plant height (cm)			Number of leaves per plant			Fresh weight (g) of plant	Dry weight (g) of plant	Days to harvest
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS			
Varieties (V)									
V_1 (Pusa Rudhira)	7.70	17.90	37.35	4.43	8.38	13.99	257.31	21.54	98.90
V_2 (Pusa Kesar)	6.72	14.19	33.06	3.74	7.40	12.67	208.66	15.92	96.13
S.Em±	0.19	0.54	0.90	0.15	0.23	0.35	3.46	0.56	0.89
CD at 5%	0.58	1.59	2.67	0.43	0.69	1.04	10.27	1.66	2.63
Fertilizer doses (F)									
F_0	5.97	13.19	31.77	2.89	6.89	11.28	204.30	16.47	100.59
F_1	6.52	14.97	33.87	3.33	7.63	12.50	221.62	17.29	99.06
F_2	7.38	15.73	35.28	4.02	7.74	13.10	231.03	18.62	97.95
F_3	8.44	19.65	38.77	5.38	8.99	15.11	263.38	21.57	93.93
F_4	7.75	16.71	36.33	4.81	8.19	14.69	244.60	19.70	96.06
S.Em±	0.31	0.85	1.42	0.23	0.37	0.55	5.46	0.88	1.40
CD at 5%	0.91	2.52	4.22	0.68	1.09	1.65	16.24	2.62	4.16

Table 2: Effect of varieties and fertilizer doses on yield, quality and profitability quality of carrot

Treatment	Root length (cm)	Root diameter (cm)	Fresh weight of Root (g)	Root yield per ha (q)	Fiber content (mg/100 g)	Specific gravity (g/cc)	TSS (^{0}Brix)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C Ratio
Varieties (V)										
V_1 (Pusa Rudhira)	27.88	3.94	94.12	313.74	818.80	1.04	8.74	156870.84	105886.85	2.07
V_2 (Pusa Kesar)	23.64	3.27	77.19	257.32	964.41	0.99	7.91	128657.65	77673.65	1.51
S.Em±	0.77	0.10	2.86	9.53	15.16	0.01	0.22	4764.34	0.09	0.35
CD at 5%	2.30	0.30	8.49	28.31	45.04	0.04	0.65	14155.58	14155.58	0.28
Fertilizer doses (F)										
F_0	22.98	3.24	69.12	230.40	826.84	0.94	6.81	115202.38	67302.38	1.41
F_1	24.51	3.43	80.17	267.22	840.07	0.98	7.86	133608.20	83272.67	1.65
F_2	25.70	3.48	84.84	282.80	894.69	1.01	8.26	141399.86	90213.77	1.76
F_3	28.08	4.12	102.67	342.22	968.35	1.09	9.66	171108.16	119071.34	2.29
F_4	27.52	3.77	91.50	305.01	928.08	1.05	9.05	152502.63	99041.09	1.85
S.Em±	1.22	0.16	4.52	15.07	23.97	0.02	0.34	7533.08	7533.08	0.15
CD at 5%	3.64	0.47	13.43	44.76	71.21	0.07	1.02	22381.93	22381.93	0.44

Conclusion

Under Malwa region of Madhya Pradesh, the performance of carrot variety Pusa Rudhira was found better than Pusa Kesar with respect to plant growth, yield, quality and profitability. Hence cultivation of Pusa Rudhira cultivar of carrot should be performed better over Pusa Kesar. Among different fertilizer doses, F_3 (NPK- 80:50:50 kg/ha) registered highest growth, yield and quality as well as maximum net return and B:C ratio. Hence, the application of NPK- 80:50:50 kg/ha with variety Pusa Rdhira can be suggested as a cost effective combination for getting higher yield with greater quality on sustainable and economical basis in carrot.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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