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Yield and yield contributing characters as influenced by integrated nutrient management and sowing methods in European carrot (*Daucus carota* L.)

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Abstract

Carrot is used as a vegetable for soups, stews, curries and pies. Grated roots are used as salad. A field experiment was conducted during rabi season of 2010-11 and 2011-12 at Experimental Farm of Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry Solan HP to access the effect of integrated nutrient management and methods of sowing on yield and quality of European carrot cultivar 'Solan Rachna'. Different organic manures and their combinations with bio-fertilizers and inorganic fertilizers along with recommended dose of fertilizer (RDF) @ 52:40:36 kg NPK ha^{-1} and two methods of sowing *viz.* ridge and flat bed method were used. The results of the present investigation revealed that treatment (T_7) involving 75% recommended dose of P + 12.5 kg *Arbuscular mycorrhizae* (AM) + recommended dose of NK gave highest root yield (265.65 qha^{-1}) and maximum benefit cost ratio (2.73:1). Among sowing methods ridge bed method of sowing was performed better than flat bed method of sowing for most of yield contributing characters. Therefore, for quality root production of European carrots, sowing on ridges along with integrated use of bio-fertilizer and inorganic fertilizers gave better results than their individual application is recommended for carrot cultivation in mid-hills of Himachal Pradesh.

Keywords: European carrot, integrated nutrient management, root yield, bio-fertilizers,

Introduction

Carrot (*Daucus carota* L.) is an important root crop. It has lot of potentialities and it is grown all over the world in spring, summer and autumn seasons in temperate countries and during winters in tropical and sub tropical areas. In India, it is grown in almost all parts of the country, both in plains and as well as in hills. In Himachal Pradesh, carrot is grown during summer and rainy season, which becomes off season vegetable in the market of north Indian plains fetching remunerative returns to the farmers. Its yield per acre remains very low and there is lot of scope to increase the production potential of carrot. Several attempts have been made to increase yield potential of root crops, but they are concerned with use of inorganic fertilizers which results in loss of soil fertility and soil health. Application of chemical fertilizers alone supply only one or two nutrients element to the crop. Moreover, the ever increasing price of these fertilizers discouraged the poor hill farmers to invest on these costly inputs. The complementary use of chemical fertilizers, organic manures, bio-fertilizers and other organics is important to maintain and sustain a higher level of soil fertility and crop productivity. FYM supplies organic matter, improves soil physical and biological environment and act as a storehouse of nutrients. Bio fertilizers render nutrients available to plant sources which these plants cannot tap themselves. Application of bio fertilizers help in improving number of biological activities of desired micro-organisms in soil and help to improve plant growth and yield. The integrated supply and use of plant nutrients from chemical fertilizers and organic manures has been shown to produce higher crop yields than when each nutrient is applied alone (Rai and Mauria, 2006). Although carrot can be grown on all types of soils, it thrives best on deep, loose and loamy soil. For early crop, a sandy loam soil is preferred, but for large yield, silt or silt loam soils are desirable. The long, smooth, slender roots desired for fresh market can successfully be grown on deep well drained light soils. Carrot grown on heavy soils tends to be more rough and coarse than those grown on light sandy soil. Therefore, in the present study an integrated nutrient management approach and ridge sowing method has been practised to assess the impact on yield and quality root production of European carrots in mid-hills of Himachal Pradesh.

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Materials and Methods

The experiment was carried out during rabi 2010-11 to 2011-12 at Vegetable Research Farm of the Department of Vegetable Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The vegetable research farm is located at an altitude of 1273 metres above mean sea level, latitude of 35.5°N and longitude of 77.8°E. Climate of the area is generally sub-temperate and semi-humid characterized by cold winters. Carrot cultivar 'Solan Rachna' was used in the present study. It is a European type cultivar having orange coloured roots with blunt end. The soil of the experimental plot was silt loam in texture having pH – 7.29, medium in organic carbon (0.99%) and available nitrogen (345.32 kg ha $^{-1}$), high in phosphorus (35.50 kg ha $^{-1}$) and low in potash (143.02 kg ha $^{-1}$) contents. Nine treatments were evaluated in Randomized Block Design (factorial) with three replications. The detail of different treatments applied is as follow:

Sr. No.	Detail of treatment
T_1	Recommended dose of NPK (52:40:36 kg/ha);
T_2	1.5 times more recommended dose of P + recommended dose of N, K;
T_3	2 times more recommended dose of P + recommended dose of N, K;
T_4	Phosphate Solubilizing Bacteria (PSB) 5 kg/ha + recommended dose of N, P, K,
T_5	*Arbuscular mycorrhizae* (AM) 12.5 kg/ha + recommended dose of N, P, K;
T_6	75% recommended dose of P + 5 kg PSB + recommended dose of N, K;
T_7	75% recommended dose of P + 12.5 kg AM + recommended dose of N, K;
T_8	75% recommended dose of PSB (3.75 kg) + 75% of AM (9.5 kg/ ha) + recommended dose of N, P, K and
T_9	Biovita granules @ 15 kg/ha

Two methods of sowing i.e. ridge and flat bed method of sowing were used. Seed were sown in lines at a spacing of 30 × 10 cm in 3.0 × 1.8 m plots. FYM @ 100 q/ha was applied at the time of field preparation for raising roots. The recommended fertilizers dose of N, P_2O_5 and K_2O @ 26:40:36 kg/ha were applied in the form of calcium ammonium nitrate, single super phosphate and muriate of potash, respectively at the time of sowing. Additional N, 26 kg/ha was applied in two equal splits (13 + 13 kg/ha) at 30 and 60 days after sowing, respectively. Seeds of carrot cultivar 'Solan Rachna' were sown after inoculation with Phosphate Solubilizing Bacteria (PSB) @ 5 kg/ha and *Arbuscular mycorrhizae* (AM) 12.5 kg/ha. Biovita granules were applied as soil application @ 15 kg/ha at the time of root formation. The observations were recorded on top length (cm), root length (cm), root: top ratio (length wise), average root weight (g), root diameter (mm), flesh thickness (mm), core diameter (mm), and root yield per hectare (q). Top length was measured in centimetres with the help of meter scale from the base of petiole to the highest point of leaves. Root/Top ratio was calculated by dividing root length to the length of leaves. Ten random roots were taken from the pooled produce and their weight recorded in grams and then average root weight calculated. Ten randomly selected roots were measured from crown to distil end in centimetres in order to measure root length. Root diameter was recorded just below the crown with the help of digital Vernier calliper in millimetres. Flesh thickness was calculated in millimetres by subtracting core diameter from root diameter. Core diameter was recorded by cutting the root just below the crown end with the help of digital Vernier calliper in millimetres. Root yield per plot was recorded in kilograms. The data recorded on various parameters were analysed for RBD-factorial design as suggested by Gomez and Gomez (1983). The results have been interpreted on the basis of 'F' test value and critical difference (CD) was calculated at 5% level of significance.

Economics of the treatments were calculated as per prevailing market price of input and output. Gross income was calculated by yield multiplied with whole sale rate of carrot. Net income was estimated by deducting the total cost of cultivation (fixed cost + treatment cost) from gross income of the particular treatment. Cost-benefit ratio was worked out by dividing net return from total cost of cultivation.

Results and Discussion

The increasing use of chemical fertilizers to increase vegetable production has been widely recognized but its long run impact on soil health, ecology and other natural resources are detrimental which affect living organisms including beneficial soil microorganism and human being. The escalating prices of chemical fertilizers and its detrimental impact on the soil, environment and human health urged the farmer to adoption of integrated plant nutrient that offers the sustainable crop production and soil fertility (Sentiyangla et al., 2010). Besides fertilizers, there are several sources of plant nutrients like organic manures, biofertilizers etc. These nutrients sources not only reduce quantity of chemical fertilizers but also improve soil fertility (Chumyani et al., 2012). Uses of organic manures in INM help mitigating multiple nutrient deficiencies.

Integrated nutrient supply involves efficient and judicious supply, management of all the major components of plant material sources *viz.* chemical

fertilizers in conjunction with animal manures, compost, green manures, legumes in cropping system, bio-fertilizers, crop residues, or recyclable waste and other locally available nutrient sources for sustaining soil fertility, health and productivity (Vithel and Kanaujia, 2013). The increase in vegetative growth might be due to the role of nitrogen in promoting vegetative growth and enhancing cell division and elongation as well as greater chlorophyll synthesis, phosphorus is easily mobilized in the plant and translocated to the meristematic zone and increase the activity of leaf formation and development in carrot and potassium activates many enzymes involved in respiration and photosynthesis. The added FYM as basal dose in integrated nutrient management would have improved the physical, chemical and biological properties of soil which helps better nutrient absorption and utilization by plant resulting better performance by the plants (Kirad *et.al.* 2010).

Integrated application of chemical fertilizers, organic manures and biofertilizers alone or in combination significantly increased the yield and yield attributing characters of carrot (Table-1). Application of 75% recommended dose of P + 12.5 kg *Arbuscular mycorrhizae* (AM) + recommended dose of NK) (T_7) recorded maximum values of all yield attributing characters such as root length (18.47 cm), root weight (141.22 g), root diameter (34.70 mm), core diameter (5.08 mm), flesh thickness (29.58 mm) and yield per plot (14.07 kg) except top length and root top ratio. These results indicate positive effects of integrating NPK with manures as well as biofertilizers. Integrated application of organic manure and inorganic fertilizer

Table 1a: Effect of Integrated Nutrient Management and sowing methods on yield and yield contributing characters of European carrot

Fertilizer treatments	Pooled data of two years (2010-11 and 2011-12)											
	Root length (cm)			Top length (cm)			Root: Top ratio (Length wise)			Average root weight (g)		
	Ridge	Flat	Mean	Ridge	Flat	Mean	Ridge	Flat	Mean	Ridge	Flat	Mean
T_1: TRD of N, P, K (52:40:36 kg/ha)	18.44	17.89	18.17	34.80	28.60	31.70	0.55	0.54	0.55	128.16	128.07	128.12
T_2: 1.5 times more RD of P + RD of NK	17.48	16.90	17.19	29.46	29.30	29.38	0.53	0.53	0.54	127.52	127.53	127.52
T_3: 2.0 times more RD of P +RD of NK	17.05	16.72	16.88	29.95	27.82	28.88	0.52	0.55	0.54	125.76	126.09	125.93
T_4: PSB (5kg/ha)+ RD of NPK	17.16	17.43	17.30	29.75	30.77	30.26	0.53	0.53	0.53	125.13	129.56	127.34
T_5: AM (12.5 kg/ha) +RD of NPK	18.74	18.15	18.45	34.03	28.90	31.46	0.55	0.60	0.56	137.94	141.81	139.88
T_6: 75% RD of P + 5kg PSB +RD of NK	16.86	17.63	17.24	32.52	29.62	31.07	0.50	0.55	0.53	130.59	132.74	131.66
T_7: 75% RD of P + 12.5 kg AM + RD of NK	19.42	17.52	18.47	34.75	29.53	32.14	0.56	0.58	0.57	141.92	140.53	141.22
T_8: 75% PSB (3.75 kg/ha) + 75% of AM (9.5 kg/ha) + RD of NPK	17.33	17.03	17.18	33.24	27.12	30.18	0.51	0.53	0.52	138.57	126.51	132.54
T_9: Biovita granules @ 15 kg/ha as a blanket application	16.67	17.48	17.08	32.76	27.13	29.94	0.52	0.56	0.55	128.27	132.50	130.38
Mean	17.68	17.42		32.36	28.75		0.52	0.57		131.54	132.37	
CD at (0.05) (Fertilizers)			0.72			NS			NS			3.00
CD at (0.05) (Sowing methods)			0.03			0.97			0.02			0.02

Table 1b. Effect of Integrated Nutrient Management and sowing methods on yield and yield contributing characters of European carrot

Fertilizer treatments	Pooled data (2010-11 and 2011-12)											
	Root diameter (mm)			Core diameter (mm)			Flesh thickness (mm)			Root yield per plot (kg)		
	Ridge	Flat	Mean	Ridge	Flat	Mean	Ridge	Flat	Mean	Ridge	Flat	Mean
T_1: TRD of N, P, K (52:40:36 kg/ha)	32.86	29.42	31.34	5.16	4.60	4.88	28.37	26.98	27.67	13.81	13.48	13.64
T_2: 1.5 times more RD of P + RD of NK	31.80	33.85	32.82	5.08	4.97	5.02	27.54	28.23	27.88	13.97	13.51	13.74
T_3: 2.0 times more RD of P +RD of NK	34.27	33.39	33.83	4.87	4.86	4.86	28.79	29.24	29.01	14.04	13.58	13.81
T_4: PSB (5kg/ha)+ RD of NPK	32.48	31.90	32.19	5.15	5.17	5.16	27.81	27.07	27.44	14.15	13.71	13.93
T_5: AM (12.5 kg/ha) +RD of NPK	33.99	33.72	33.86	4.62	5.23	4.92	30.00	29.93	29.97	14.28	13.62	13.95
T_6: 75% RD of P + 5kg PSB +RD of NK	33.45	32.53	32.99	4.59	4.52	4.55	27.49	26.84	27.17	13.62	13.81	13.71
T_7: 75% RD of P + 12.5 kg AM + RD of NK	35.34	34.07	34.70	4.85	5.31	5.08	29.91	29.26	29.58	14.01	14.13	14.07
T_8: 75% PSB (3.75 kg/ha) + 75% of AM (9.5 kg/ha) + RD of NPK	32.92	31.00	31.96	4.86	4.38	4.62	27.89	26.12	27.01	13.89	13.50	13.70
T_9: Biovita granules @ 15 kg/ha as a blanket application	32.33	31.81	32.07	4.09	4.54	4.31	27.85	26.11	26.98	13.74	13.54	13.64
Mean	33.40	32.71		4.81	4.84		28.40	27.75		13.95	13.65	
CD at (0.05) (Fertilizers)			1.45			0.40			1.43			0.17
CD at (0.05) (Sowing methods)			NS			NS			NS			0.08

Table 2. Economics of various treatments for root production of European carrot

Detail of treatments	Yield (q/ha)	Gross income (Rs/ha)	Total cost of cultivation (Rs/ha)	Net return (Rs/ha)	B : C ratio
T_1: RD of N, P, K (52:40:36 kg/ha)	252.73	2,52,730	68,905	1,83,825	2.67:1
T_2:1.5 times more RD of P + RD of NK	254.49	2,54,490	69,322	1,85,168	2.67:1
T_3:2.0 times more RD of P +RD of NK	256.51	2,56,510	69,760	1,86,750	2.68:1
T_4:PSB (5kg/ha)+ RD of NPK	258.20	2,58, 200	69,975	1,88,852	2.69:1
T_5:AM (12.5 kg/ha) +RD of NPK	258.51	2,58,510	69,548	1,88,484	2.71:1
T_6:75% RD of P + 5kg PSB +RD of NK	253.85	2,53,850	69,139	1,84,711	2.67:1
T_7:75% RD of P + 12.5 kg AM + RD of NK	260.65	2,60,650	69,805	1,90,845	2.73:1
T_8:75% PSB (3.75 kg/ha) + 75% of AM (9.5 kg / ha) + RD of NPK	254.36	2,54,360	70,071	1,84,289	2.63:1
T_9:Biovita granules @ 15 kg/ha as a blanket application	251.81	2,51,810	69,456	1,85,354	2.62:1

increased the availability of NPK and also improved the fertility status of soil and productivity due to which yield attributing characters might have increased. This might be due to corresponding response to increased growth and yield attributing characters attained previously under this treatment. Sagiv et al. (1994) reported that highest yield was obtained in carrot when organic manure, composted refuses and N fertilization was applied in combination. Rani et al. (2006) reported that application of neem cake and castor cake in combination with half the recommended dose of NPK recorded maximum root yield (25.860 t ha^{-1}) in carrot. Sentiyangla et al. (2010) observed maximum yield in radish by combination of NPK, FYM and biofrtilizers. Subenthung et al. (2012) observed that maximum root yield was obtained in the combined application of 50% pig manure + 50% NPK in turnip.

As regards sowing methods, raised bed method of sowing was found better than flat bed method. Ridge sowing method performed better for root length (17.68 cm), top length (32.36 cm), root top ratio (0.52), average root weight and yield per plot (13.95 kg). However, root diameter, core diameter and flesh thickness (29.58 mm) exhibited non-significant influenced by the sowing methods. Babik and Dudek (2000) reported that cultivation on the ridges enable the higher yield of better quality. This may be due to good aeration and proper drainage in ridge bed sowing. Also soil gets warmed up early in ridges as compared to flat beds and hence enhanced the shoot growth. Rubatzky *et al.* (1990) reported that well prepared seed beds whether raised or flat, improved uniformity of soil depth and subsequent emergence of seedling development. Raised beds improved drainage and soil aeration and facilitate furrow irrigation, cultivation and other cultural operations. Raised beds in cooler climates can also contribute to slightly increased soil temperature, which in some situations can reduce the growing period by several days to as much as 1-2 weeks.

The economics and net profit were calculated on the basis of cost of cultivation and market price of the produce. It is evident from Table 2 that the integration 75% recommended dose of P + 12.5 kg AM + recommended dose of NK (T_7) was found to be the most profitable treatment in carrot exhibiting highest net return of Rs. 1, 90, 845 per hectare with cost benefit ratio of 1: 2.73. The reason of high profitability in this treatment of integration (organic + inorganic) can be due to lower cost of inputs and higher yield. Similar results were also reported by Chumyani et al. (2012) in tomato and Vimera et al. (2012) in king chilli. They found highest net return with the combined application of 50% NPK + 50% FYM + Biofertilizers.

It can be concluded from the experiment that integrated integration 75% recommended dose of P + 12.5 kg AM + recommended dose of NK (T_7) was found optimum for getting maximum productivity of carrot without reducing fertility status of soil. This treatment reduced N chemical fertilizers without any compromise on yield of carrot and fertility of soil. Therefore, this may be recommended for sustainable yield of carrot and to nourish the soil fertility under mid-hills condition of Himachal Pradesh.

सारांश

गाजर का उपयोग सब्जी, सूप, करी, स्टीयूज, करी एवं पाइज के लिये किया जाता है। कसा हुआ गाजर का उपयोग सलाद के लिए किया जाता है। समन्वित पोषक तत्व प्रबंधन एवं बुआई की विधि का उपज एवं गुणवत्ता ज्ञात करने के लिए प्रजाति 'सोलन रचना' को समाहित कर सब्जी विज्ञान विभाग, डा. वाई एस परमार उद्यान विश्वविद्यालय एवं वानिकी, सोलन में वर्ष 2010–11 तथा 2011–12 के रबी मौसम में प्रयोग किया गया। विभिन्न प्रकार के कार्बनिक खाद एवं उनके मेल को जैव उर्वरकों तथा अकार्बनिक उर्वरकों के साथ संस्तुत उर्वरक की मात्रा दर 52:40:36 किलोग्राम नत्रजन, फास्फोरस एवं पोटाश प्रति हेक्टेयर तथा बुआई की दो विधियों यानी उठी मेड़ तथा समतल क्यारी का उपयोग किया गया। वर्तमान परीक्षण से स्पष्ट होता है कि शोधन (टी.–7) जिनमें संस्तुत मात्रा का 75 प्रतिशत फास्फोरस + 12.5 किलोग्राम आर्ब्सकुलर माइकोराइजी (ए एम) + नत्रजन, पोटाश की संस्तुत मात्रा से अधिकतम जड़ उपज (265.65 कु./हे.) एवं अधिकतम लाभ–लागत अनुपात (2.73:1) प्राप्त हुआ। बुआई की विधियों में उठी हुई मेड़ विधि, समतल क्यारी तुलना उपज

निर्धारक गुणों हेतु उत्तम पायी गयी। इस प्रकार यूरोपियन गाजर के गुणवत्तायुक्त उपज के लिए मेड़ों पर बुआई के साथ–साथ जैव उर्वरकों एवं अकार्बनिक उर्वरकों के समन्वित प्रयोग से उत्तम परिणाम, किसी अकेले के प्रयोग से अच्छा है जिसे हिमाचल के मध्य पहाड़ियों में गाजर की खेती करने के लिए अपनाया जा सकता है।

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