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Planting row arrangement and nutrient management in geranium (*Pelargonium graveolens*) - garlic (*Allium sativum*) intercropping

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ABSTRACT

Field experiments were carried out at Lucknow, India to evaluate the optimum plant row arrangement of geranium and to study the effects of different rates of fertilizer N, P and Zn for the yield assessment in a geranium-garlic intercropping system. A paired row arrangement (40/80 cm) of geranium planting significantly increased the herb and essential oil yield over the conventional single row planting method (60x30cm). The former gave 20.6 % more herbage than the geranium single row intercrop system, with a 22.3 % increase in oil yield. Application of N at 160 kg ha^{-1} significantly increased the herb and oil yields of geranium and bulb yield of garlic over the control and 80 kg N ha^{-1}. Uptake of N by geranium was also significantly higher at 160 kg N ha^{-1}.Application of phosphorus at 40 kg P_2O_5 ha^{-1} proved significantly better than the no P control in the production of geranium oil and garlic bulbs. Uptake of Zn increased significantly up to 40 kg P_2O_5 ha^{-1}. Higher rates of P decreased the Zn uptake by the plants. Application of 30 kg Zn SO_4 ha^{-1} showed a significant response on the herb and oil yields over the no zinc control. The higher growth indices such as monetary equivalent ratio (1.45), area time equivalent ratio (1.44), land use efficiency (144 %) and benefit cost ratio (6.37) were recorded with a geranium paired intercrop system compared to other cropping systems. The geranium paired intercrop system proved advantageous in enhancing the economic returns by 1.73 – a two fold increase over the geranium single row, sole cropping system. It is concluded from this study that intercropping of garlic with a geranium paired row system proved highly beneficial in terms of getting higher economic returns by almost a factor of two over the conventional geranium single row planting method. A fertilizer addition of 160 kg N, 40 kg P_2O_5 and 30 kg Zn SO_4 ha^{-1} is recommended for achieving the maximum yield advantages in a geranium-garlic intercropping system.

Key words: Geranium-garlic intercropping, Plant row arrangement, Nutrient management.

INTRODUCTION

Geranium (*Pelargonium graveolens*) is cultivated as an annual crop in some parts of the northern Indian plains for its high value essential oil which is extensively used in perfumery and cosmetic industries. The oil contains about 25 % citronellol and 18 % geraniol. The current international demand of about 600 tonnes geranium oil is being largely met by China, Morocco, Egypt, Reunion Island and South Africa (Qinghua, 1993; Anonymous, 1996). Against the yearly consumption of about 150 tonnes requirement of geranium oil, India produces a meager quantity of about 5 tonnes per year. Therefore, most of the 145 tonnes Indian requirement of geranium oil is being largely met through imports. In an attempt to increase the production of geranium oil, successful efforts have been made to introduce the crop and to develop appropriate agro-technologies for its commercial cultivation, in the north Indian plains (Ram *et al*, 1995; Ram *et al.*, 1997; Ram *et al*., 2003). In view of rising human population pressure on the earth, any possibility of further increasing the area for monocropping of geranium and spice (garlic) crops is not permissible as most of the arable area must be kept for the production of food grains. Under such conditions, the alternative approach for increasing the production of geranium oil and garlic appears to be an increase in productivity per unit area and time through a intercropping system. The yield advantages of intercropping have been reported by a number of workers (Fukai and Trenbath, 1993 ; Ram and Kumar, 1998).

It has also been shown from an earlier, preliminary study that garlic could be one of the better intercrops with geranium because of the dissimilar growth pattern (Ram and Kumar, 1998). However, the yield potential of geranium with conventional planting method could not be realized due to less inter row space. To sustain the optimum level of production and to minimize the intercrop competition for growth resources, an alteration in planting arrangement of geranium is required to be standardized, enabling to create more space to grow a component crop between two pairs of the main crop. However, the optimum plant row arrangement

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of geranium in an intercropping system has not been worked out, so far. Among the nutrients, nitrogen, phosphorus and zinc are the major constraints, which affect the crop growth and yields to a greater extent.

In this study an attempt has been made to determine the optimum planting row arrangement in geranium and to work out the nutrient requirement of geranium with garlic in an intercropping system to achieve maximum yield advantages by way of improving resource utilization efficiency.

MATERIAL AND METHODS

Experimental site: The experimental farm of the Central Institute of Medicinal and Aromatic Plants, Lucknow is located at 26.5^0 N latitude, 80.5^0 E longitude and at 120 m altitude, representing the semiarid-subtropical climate with hot summers and fairly cool winters. The experimental sites receive on an average about 1050 mm rain annually, most in the month July-September.

Experiment 1

Soil Characteristics: The soil of the experimental area was a sandy loam in texture and alkaline in reaction (pH 8.3). The nutrients in the 0-15 cm soil layer were; available N 196.9 kg / ha (Subbiah and Asija, 1956), available P_2O_5 32.3 kg / ha (Olsen *et al.*, 1954) and available K_2O 63.6 kg / ha (Jackson, 1967).

Treatment and crop culture: The field experiment was conducted during winter-summer season. The twenty eight treatment combinations comprising of 7 cropping systems (geranium sole at 60 x 30 cm, geranium sole at 80 x 30 cm, geranium paired sole at 40/80 cm, garlic sole at 20 x 10 cm, geranium + garlic (1:3), geranium + garlic (1:4) and geranium + garlic (1 pair : 4) and 4 levels of nitrogen (0,80,160 and 240 kg N/ha) were evaluated in a factorial randomized design block with three replications. The variety Bourbon of geranium was selected for this study. The terminal cuttings of geranium were planted at a plant spacing of 60 x 30 cm, 80 x 30 cm and paired row pattern (pair to pair 80 cm and with in the pair 40 cm) on 6 December, accommodating 55555, 41666 and 55555 cuttings per hectare. Immediately after planting, a light irrigation was given to ensure better establishment and good sprouting of cuttings. The garlic cloves were planted at a plant spacing of 20 x 10 cm on 15 December. A uniform dose of phosphorus and potassium fertilizers each of 60 kg P_2O_5 and K_2O ha^{-1} as single super phosphate (16% P_2O_5) and murate of potash (60% k_2O), respectively, was applied basally at the time of planting, Nitrogen was applied as urea as per the treatment in three equal splits, 45 and 80 days after planting and one week after the first harvest. The geranium crop was harvested twice, 150 days after planting (DAP) and 52 days after the first harvest, respectively. Terminal and lateral branches with 10-12 leaves were cut for oil extraction, leaving two to three buds intact for regeneration of harvested shoots. The garlic crop was harvested at 140 days after planting.

Studies: Growth and yield observations of geranium and garlic were recorded at harvests. The oil content in the fresh plant samples was determined by hydro steam distillation method using Clevenger's apparatus. Oil yield was calculated by multiplying the fresh herbage yield with that of oil content in respective plant samples and expressed as oil yield kg ha^{-1}. The nitrogen in the plant samples was estimated by the micro –kjeldhal method (Jackson, 1967). Uptake of N was computed using the dry matter yield and its N content.

Land equivalent ratio (LER) was used to quantify the land use efficiency of the intercrop system (Mead and Willey, 1980). Area time equivalent ratio (ATER) was calculated to determine the yield advantage considering the duration of cropping period. The formula suggested by Hiebsch and Mc Collum (1987) was adopted. Relative species competition in the intercrop was evaluated using competitive ratios (CR) as per the formula suggested by Willey and Rao (1980). The monetary equivalent ratio (MER) employed was the sum of the ratios of intercrop monetary return to the highest sole crop monetary return from the entire land area occupied by all intercrops unit time and calculated as per the formula suggested by Adetiloye and Adekunle (1989).

The intercrop yields of garlic were converted into main crop equivalent yield (MCEY).

Land use efficiency (LUE) is generally computed as per the formula mentioned below.

$$LUE\ (\%) = LER \times 100$$

Benefit: Cost ratio is the ratio of net return to cost of production. It was calculated as per the formula described below:-

B : C ratio =
Annual net return (Rs ha-1) / Annual cost of production (Rs ha-1)

Experiment 2

This experiment was conducted in the same field in which experiment I was carried out in the previous year. The soil of the field plot was low in nitrogen (168.9 kg N ha^{-1}) and potassium (82.7 kg K_2O ha^{-1}) and medium in phosphorus status (21.6 kg P_2O_5 ha^{-1}). The available Zn was 0.4 ppm, estimated by DTPA $CaCl_2$ TEA method.

Treatment and crop culture: The eighteen treatment combinations consisting 3 cropping systems viz geranium paired sole (40/80 cm), garlic sole, geranium + garlic (1 pair : 4), 3 levels of phosphorus (0, 40 and 80 kg P_2O_5 ha^{-1}) and 2 levels of zinc (0 and 30 kg $ZnSO_4$ ha^{-1}) were evaluated in a factorial randomized block design with three replications.

Terminal cuttings of geranium were planted on 2 December. The garlic cloves were planted at on 8 December. A uniform dose of nitrogen and potassium fertilizers were applied in all the plots at the rate of 160 kg N and 60 kg K_2O ha^{-1}, respectively. The potassium, phosphorus and zinc fertilizers were applied as a basal dose at the time of planting. The geranium crop was harvested twice, first on 27th April and second on 18th June, respectively. The garlic crop was harvested on 29th April, respectively. The studies carried out in this experiment were similar to the experiment 1.

RESULTS AND DISCUSSION

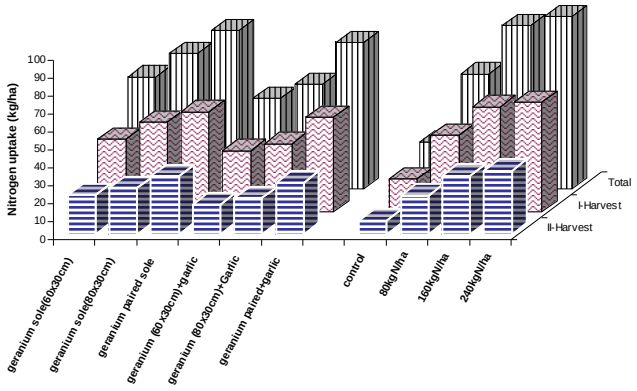
Experiment 1

Herb and oil yields of main crop: Paired intercrop and pure crop systems significantly enhanced the herbage yield, over the sole crop of conventional single row planting method at harvests (Table 1). The increase in the oil yield of geranium due to paired intercrop system was 24.7 and 10.2%, over the sole crops of geranium planted at 60 x 30 cm and 80 x 30 cm, respectively, at first harvest. The corresponding increase in oil yield for the second harvest was 18.8 and 13.5%. Total oil yield was also significantly higher with paired intercrop system over the sole crop of single row planting method. The possible reason for the increase in biomass and essential oil production in paired system was because of pairing of two geranium rows, resulting more space for the better growth of the lateral shoots. Significance of relativity more space allocation per plant with paired row planting system, as against single row spaced plants to enhance total production has been reported by Prakasha Rao *et al*. (1984) in geranium.

The data showed that application of N at 160 kg ha^{-1} significantly increased the herbage and oil yields, over the control and 80 kg N ha^{-1} at first, second and total of both the harvests. These results are in close agreement with those reported by Ram *et al.* (2003).

Nitrogen uptake by the crop: Uptake of N by the crop, in general, was higher in the first than the second harvest crop. Uptake increased significantly with geranium paired system than other cropping systems at first, second and total of both the harvests (Fig.1). This was probably because of more space assigned to each plant in geranium paired cropping system. Hence, the respective cropping system utilized the growth resources more effectively than other cropping systems. The better utilization of N in non legume- non legume intercropping system has been reported by Morris and Garrity (1993).

Fig.1: Nitrogen uptake(kg/ha)of geranium as influenced by different cropping systems and rates of nitrogen



Uptake of N increased significantly with the increase in N level up to 160 kg ha^{-1}. The higher doses of N increased the N concentration in the plant tissue and also the herbage production, which ultimately led to the increased uptake of N.

Intercrop productivity

Growth: Data presented in Table 2 showed that plants of garlic did not differ significantly in height, green leaves and shoot : bulb ratio between the treatments of garlic sole and

TABLE 1 Herb and oil yields of geranium as influenced by different cropping systems and rates of nitrogen application

Treatment	Herb yield (t ha^{-1})			Oil yield (kg ha^{-1})		
	First harvest	Second harvest	Total	First harvest	Second harvest	Total
Cropping Systems						
Geranium sole (60 x 30 cm)	14.12	9.86	23.98	28.50	20.25	48.75
Geranium sole (80 x 30 cm)	16.16	10.69	26.86	32.64	21.20	53.84
Geranium paired sole (40/80 cm)	18.78	13.16	31.94	37.98	26.67	64.66
Geranium (60x 30 cm) + garlic	12.33	8.01	20.34	24.67	16.07	40.74
Geranium (80 x 30 cm)+ garlic	13.06	8.74	21.80	27.01	17.86	44.87
Geranium paired (40/80 cm) + garlic	17.15	11.77	28.91	35.55	24.06	59.60
CD at 5%	2.09	1.34	3.60	3.43	2.41	6.15
Nitrogen levels (kg ha^{-1})						
0	10.17	6.24	16.41	21.35	13.55	34.90
80	14.90	9.79	24.69	31.09	21.25	52.34
160	17.58	12.24	29.82	35.73	24.32	60.05
240	18.41	13.21	31.62	36.06	24.95	61.01
CD at 5%	1.71	1.10	2.94	2.80	1.97	5.02

garlic intercrops. There was also a non significant response of different levels on N on green leaves/plant and shoot: bulb ratio. This might be due to the plants that attained maturity at 140 days crop, resulting dryness of leaves.

Yield and yield attributes of garlic: The diameter of garlic bulbs and weight per bulb were not influenced significantly by different cropping systems at harvest (Table 2). However, number of cloves/bulb recorded from geranium paired intercrop system was significantly higher than the geranium planted at 60 x 30 cm spacing. But, significantly lower bulb yield from geranium paired system than the garlic sole crop system was because of the less plant population of garlic by 33% in the former treatment.

Application of N at 160 kg ha^{-1} significantly increased the diameter, number of cloves / bulbs, weight / bulb and bulb yield as compared to the control and 80 kg N ha^{-1}. The higher bulb yield of garlic at increased doses of N has been reported by Setty *et al.,* (1989).

Quantification of efficiency of resources use

Land Equivalent Ratio (LER): Data on LER showed that intercropping of garlic with geranium resulted in greater LER values ranging from 1.66 to 1.71, which indicated that about 69% more land would have to be planted to sole crops to achieve similar yield of geranium and the component crop (Table 3). The total productivity of land was higher under garlic + geranium system as indicated by ATER values of 1.43 - 1.44.

Land Use Efficiency (LUE): The LUE values indicated that the intercropping of garlic with geranium (80 x 30 cm) showed the highest land use efficiency of 171%, as against 166% with geranium paired intercrop system. The CR values approaching unity showed that garlic was less aggressive in suppressing the growth of main crop of geranium. But CR value of 1.55 with geranium paired intercrop system was because of less plant population of garlic by 33% as compared to sole crop of garlic.

Monetary Equivalent Ratio (MER): The values of MER indicated that the highest monetary return (MER, 1.45) was obtained from geranium paired intercrop system followed by other cropping systems. Obviously, the paired intercrop and geranium (80 x 30 cm) intercrop systems showed an additional monetary benefit in the range of 31- 45 %, over the sole crops of geranium.

TABLE 2 Growth and yield traits of garlic as influenced by different cropping systems and rates of N application

Treatment	Plant height (cm)	Green leaves/plant	Shoot : bulb ratio	Dia meter /bulb (cm)	No. of Cloves / bulb	Weight / bulb (g)	Bulb yield (t ha^{-1})
Cropping Systems							
Garlic Sole (20 x 10 cm)	34.98	3.25	0.32	4.37	22.85	32.77	14.09
Geranium (60x 30 cm) + garlic	30.80	3.28	0.35	4.18	18.58	31.54	12.00
Geranium (80 x 30 cm)+ garlic	31.65	3.43	0.36	4.17	21.00	32.34	12.38
Geranium paired (40/80 cm) + garlic	33.55	3.41	0.32	4.26	22.23	33.63	10.40
CD at 5%	N.S.	N.S.	N.S	N.S.	2.10	N.S.	1.55
Nitrogen levels (kg ha^{-1})							
0	23.25	2.80	0.37	3.28	13.95	23.32	7.43
80	30.78	3.36	0.33	3.85	18.43	29.51	11.37
160	38.22	3.55	0.33	4.82	25.51	37.57	14.49
240	38.73	3.65	0.32	5.02	26.78	39.90	15.58
CD at 5%	3.22	0.30	0.03	0.38	2.10	3.50	1.55

NS= non significant

TABLE 3 Resource use efficiency of geranium - garlic intercropping systems

Treatment	**LER**	**ATER**	**LUE (%)**	**CR** M	I	**MER**	**MCEY (kg ha^{-1})**
Cropping Systems							
Geranium sole (60 x 30 cm)	1.00	-	-	-	-	-	48.75
Geranium sole (80 x 30 cm)	1.00	-	-	-	-	-	53.84
Geranium paired sole (40/80 cm)	1.00	-	-	-	-	-	64.66
Garlic Sole (20 x 10 cm)	1.00	-	-	-	-	-	46.96
Geranium (60x 30 cm) + garlic	1.69	1.43	169.00	1.0	0.98	1.19	80.72
Geranium (80 x 30 cm)+ garlic	1.71	1.44	171.00	1.0	0.89	1.31	86.14
Geranium paired (40/80 cm) + garlic	1.66	1.43	166.00	1.0	1.55	1.45	94.27

LER = Land equivalent ratio, ATER =Area time equivalent ratio, LUE (%) = Land use efficiency , CR= Competitive ratio, MER= Monetary equivalent ratio, MCEY= Main crop equivalent yield.
M= Main crop. 1= Intercrop

Main crop equivalent yield (MCEY): The total main crop equivalent yield was higher (94.27 kg ha^{-1}) in the paired intercrop system, which indicated that intercropping of garlic with geranium paired system was highly beneficial in terms of better resource utilization of enhancing the total farm production from unit area and time.

Gross and net returns: Gross and net returns from geranium paired intercrop system with garlic was higher (Rs.3,17,090 ha^{-1} and Rs. 2,74,050.45 ha^{-1}) than other cropping systems (Table 4). The higher net return due to intercropping has been reported in food and medicinal and aromatic crops (Singh and Shivraj,1998). The geranium paired + garlic intercropping system gave a higher B : C ratio of 6.37 as compared to other intercropping systems, which indicates the profit of Rs. 6.37 on one rupee investment.

Experiment 2

Herb and oil yields of main crop: It will be seen from the data presented Table 5 in that herb and oil yields recorded from intercrop system was at par of its sole crop system at first and second harvests. Application of P at 40 kg P_2O_5 ha^{-1} significantly enhanced the herb and oil yields, over the control. Application of 30 kg $ZnSO_4$ significantly increased the herb and oil yields, over the control.

Uptake of P and Zn: Uptake of P by geranium sole and intercrop systems was not influenced significantly at first, second and total of both the harvests (Fig2). The uptake of P showed a significant response up to 80 kg P_2O_5 ha^{-1}, at harvest. Application of 30 kg $ZnSO_4$ ha^{-1} also proved significantly superior to control in the uptake of P by the crop. Prakasa Rao *et al.* (1988) reported the higher uptake of P by geranium plants with higher rates of P application.

Fig.2: Uptake of P(kg / ha)by geranium as influenced by different cropping systems and rates of phosphorus and zinc

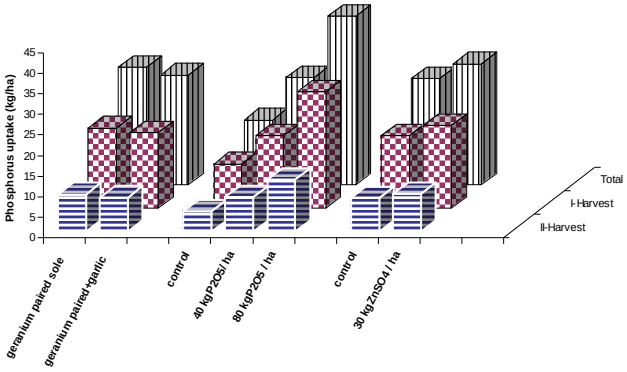


TABLE 4 Economics of geranium - garlic intercropping systems

Treatment	Oil yield of geranium(kg ha^{-1})	Bulb yield of garlic (kg ha^{-1})	Gross return (Rs. ha^{-1})	Cost of production (Rs. ha^{-1})	Net profit (Rs. ha^{-1})	B:C Ratio
Cropping Systems						
Geranium sole (60 x 30 cm)	57.50	-	1,72,500.00	36,260.64	1,36,239.36	3.76
Geranium sole (80 x 30 cm)	64.14	-	1,92,420.00	33,444.60	1,58,975.40	4.75
Geranium paired sole (40/80 cm)	75.34	-	2,26,020.00	37,571.00	1,88,449.00	5.02
Geranium (60x 30 cm) + garlic	48.99	11995	2,66,920.00	41,934.25	2, 24,985.75	5.37
Geranium (80 x 30 cm)+ garlic	53.96	12380	2,85,680.00	38,764.00	2,46,916.00	6.37
Geranium paired (40/80 cm) + garlic	71.03	10400	3,17,090.00	43,039.50	2,74,050.45	6.37

N=Rs. 9.87 kg^{-1}, P= Rs. 19.5 Kg^{-1}, K= Rs. 7.10 kg^{-1}, Geranium Oil = Rs. 3000.00 kg^{-1},Garlic bulb= Rs. 10.00 kg^{-1}

TABLE 5 Herb and oil yields of geranium as influenced by different cropping systems and rates of Phosphorus and zinc application

Treatment	Herb yield (t ha^{-1})			Oil yield (kg ha^{-1})		
	First harvest	Second harvest	Total	First harvest	Second harvest	Total
Cropping Systems						
Geranium paired sole (40/80 cm)	23.69	15.25	38.99	48.72	32.98	81.73
Geranium paired (40/80 cm) + garlic	21.77	14.04	35.82	44.98	30.37	75.35
CD at 5%	1.75	N.S.	2.85	3.49	2.40	5.92
Phosphorus levels (kg P_2O_5 ha^{-1})						
0	19.46	12.31	31.76	40.33	27.05	67.38
40	23.78	15.31	39.10	49.05	33.70	82.75
80	24.97	16.31	41.28	51.17	34.28	85.5
CD at 5%	2.15	1.55	3.49	4.28	2.94	7.25
Zinc levels (kg $ZnSO_4$ ha^{-1})						
0	21.42	13.74	35.17	44.30	29.72	74.00
30	24.05	15.55	39.59	49.40	33.63	83.08
CD at 5%	1.75	1.26	2.85	3.49	2.40	5.92

N. S.= Non significant

TABLE 6 Growth and yield traits of garlic as influenced by different cropping systems and rates of Phosphorus and Zinc application

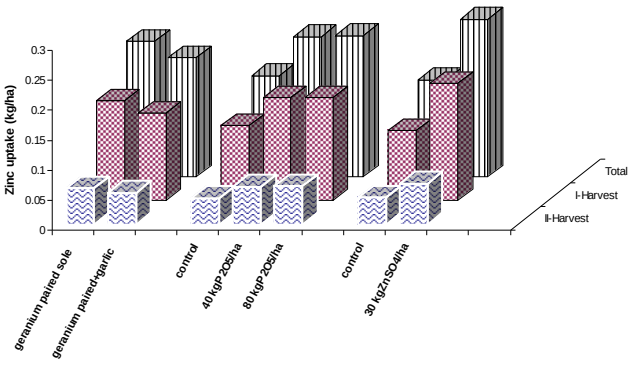
Treatment	Plant height (cm)	Green leaves /plant	Shoot : bulb ratio	Dia meter /bulb (cm)	No. of Cloves / bulb	Weight / bulb (g)	Bulb yield (t ha^{-1})
Cropping Systems							
Garlic Sole (20 x 10 cm)	31.59	6.13	0.43	4.55	15.82	32..11	12.22
Geranium paired (40/80 cm) + garlic	33.24	5.77	0.35	3.79	15.50	26.00	5.63
CD at 5%	N.S.	N.S.	0.03	0.33	N.S.	2.34	0.73
Phosphorus levels (kg P_2O_5 ha^{-1})							
0	31.42	5.53	0.43	3.90	12.97	22.17	8.00
40	32.54	6.08	0.38	4.19	16.18	29.50	9.08
80	33.30	6.23	0.37	4.42	17.83	35.50	9.70
CD at 5%	N.S.	0.57	0.04	0.40	1.66	2.86	0.89
Zinc levels (kg $ZnSO_4$ ha^{-1})							
0	32.20	5.85	0.41	4.06	14.61	26.61	8.55
30	32.63	6.05	0.38	4.28	16.71	31.50	9.31
CD at 5%	N.S.	N.S.	N.S.	N.S.	1.35	2.34	0.73

N.S. = Non -significant

Uptake of Zinc by geranium plants influenced significantly with geranium sole compared with that of geranium intercrop system at first, second and total of both the harvests (Fig 3.).Uptake of Zn at 40 kg P_2O_5 ha^{-1} increased significantly, over the control at harvests. The total uptake of Zn by geranium plants at 40 kg P_2O_5 ha^{-1} was 38.5% over the control. Application of Zn at 30 kg ha^{-1} increased the uptake of Zn by 66.7,51.1 and 62.3% over the control, at first, second and total of both the harvests, respectively. The lower doses of P (40 kg P_2O_5 ha^{-1}) with Zn application has been proved superior to higher doses of P in maize (Takkar *et al*., 1976).

Intercrop productivity: Growth attributes of garlic such as plant height and number of green leaves per plant were observed to be non significant between the treatments intercrop and sole crop of garlic (Table 6). It may be noticed that garlic plants approaching to maturity after 120 days, resulting dryness of leaves.

Fig.3: Uptake of Zn (kg / ha) by geranium as influenced by different cropping systems and rates of phosphorus and zinc



`Application of phosphorus at 80 kg P_2O_5 ha^{-1} gave significantly higher number of green leaves per plant, over the control. Increasing rates of P significantly decreased the shoot: bulb ratio over the control. Application of zinc at 30 kg $ZnSO_4$ ha^{-1} did not show any significant difference in the plant height, green leaves per plant and shoot: bulb ratio, over the control. This effect was due to relatively better growth of under ground bulbs than the above ground parts. The reduction in shoot: bulb ratio with zinc application might be due to early induced maturity.

The diameter, no. of cloves and weight / bulb and bulb yield showed that these characters were influenced significantly with sole crop of garlic than the intercrop of garlic, except cloves per bulb. The bulb yield of garlic sole was increased by almost two times than the garlic intercrop.

This can be explained on the basis of (i) the plant population of intercropped garlic was less by 33% compared with that of 100% population of garlic sole crop, (ii) infestation of garlic intercrop plants with basal rot diseases. Garlic bulb yield was found to be increased with increase in the application of phosphorus up to 40kg P_2O_5 ha^{-1} only. Increase rate of P from 40 to 80 kg P_2O_5 ha^{-1} did not influence the bulb yield significantly. Application of Zinc at 30 kg $ZnSO_4$ ha^{-1} significantly increased the bulb yield of garlic, over the control.

Quantification of efficiency of resource use: The total productivity of land was higher under geranium + garlic system as indicated by ATER values of 1.24. Morris and Garrity (1993) reported that the combined root system in intercropping is likely to be the larger and functional for a longer duration under intercrop than either of sole.

CONCLUSIONS

It may be inferred from these experiments that geranium paired system (40/80cm) was proved significantly superior to single row (60 x 30 cm) method of planting in the production of essential oil. The geranium paired intercrop system enhanced the economic returns by almost two folds than the single row planting method. To optimize the benefits of nitrogen, phosphorus and zinc fertilizers, a dose of 160 kg N, 40 kg P_2O_5 and 30 kg Zn SO_4 ha^{-1} is suggested for achieving the maximum yield advantages in geranium-garlic intercropping system.

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