EFFECT OF CROP GEOMETRY AND FERTILITY LEVELS
ON GROWTH, YIELD AND QUALITY OF *KHARIF* ONION (*ALLIUM CEPA* L.) CV. N-53 IN SEMI-ARID CONDITIONS

THESIS

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This is to certify that **Mr. ANIL KUMAR SONI** successfully completed the preliminary examination held on 03rd September, 2001 as required under the regulation for **Doctor of Philosophy** degree.

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This is to certify that this thesis entitled **"Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions",** submitted for the degree of **Doctor of Philosophy** in the subject of **Horticulture** embodies bonafide research work carried out by **Mr. ANIL KUMAR SONI** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 26th April, 2004.

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This is to certify that this thesis entitled **"Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions"**, submitted by **Mr. ANIL KUMAR SONI** to Rajasthan Agricultural University, Bikaner in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** in **Agriculture** in the subject of **Horticulture** after recommendation by the external examiner was defended by the candidate before the following members of the advisory committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory, we therefore, recommend that the thesis be approved.

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This is to certify that **Mr. ANIL KUMAR SONI** of the **Department of Horticulture**, S.K.N. College of Agriculture, Jobner has made all corrections/modifications in the thesis entitled **"Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions",** which were suggested by the external examiner and the advisory committee in the oral examination held on -----------2004. The final copies of the thesis duly bound and corrected were submitted on---------- ---2004, are enclosed herewith for approval.

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Date

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1. INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important crops among bulb as well as cash crops. it belongs to family Alliaceae. It is semi-perishable in nature and can be transported to a long distance without much injury.

Onion is a biennial or perennial herb which give off a distinctive and pungent odour, when tissues are crushed. The green leaves and immature and mature bulbs are eaten as raw or preparing vegetables. The onions are used for condiments, salad, preparing chutneys, pickles, curries, soups, sauces and seasoning foods. The small bulbs and shallots are pickled in vinegar or brine. Now a days, dehydrated bulbs or onion powder is in great demand, which reduces transport cost and storage losses. Onion is rich in protein, calcium, phosphorus and carbohydrates (Aykroyd ,1963 and Bose *et al*., 1989).

The crushed bulb contains colourless, odourless volatile oil known as allyl propyl disulphide. It is reaches highest just before fall of top in the field. The outer skin colour is due to the presence of querctin. Nadkarni (1954) reported many medicinal properties of onion. Onions are diuretic, applied on bruises, boils and wounds. It relieves heat sensation. Onion juice is used as smelling on hysterial fits in faintness. It is used to relive insect bites and soar throat.

India ranks second in onion production which shares 5 per cent of total vegetable production. India produces about 4.85 mt onion from 0.52 mha area (Anonymous, 2002). The main onion growing states in our country are Maharasthra, Madhya Pradesh, Gujarat, Karnataka, Rajasthan, Tamil Nadu, Andhra Pradesh, Uttar Pradesh and Orissa. In Rajasthan, it is grown on an area of 20193 ha with the production of 120723 Mt and productivity of 5.98 t/ha (Anonymous, 1999).

Generally, onion is cultivated in *rabi* season but early *kharif* and late *kharif* crops are also taken in various parts of the states like Maharasthra, Karnataka, Gujarat, Andhra Pradesh and Tamil Nadu. During october.- November, generally there is shortage of onion in the market which leads to heavy prices. Therefore, production of onion in *kharif* season is more important to have continuous supply of onion round the year. Farmers also get good return from *kharif* season crop. However in Rajasthan, *kharif* onion is cultivated in very less area due to the unawarness and lack of suitable production technology. Therefore, there is a need to standardize production technology for *kharif* season onion in the state. The optimization of crop geometry is an important factor which has direct influence on growth, bulb yield and quality. Closer spacing accommodate more number of plants in per unit area, which results in higher bulb yield of comparatively smaller size. Alternatively, wider spacing leads to comparatively low yield with better size of bulbs. Generally onion sets are used to grow *kharif* season crop. These sets are planted on both side of ridges in *kharif* season (Selvaraj, 1993).

Besides crop geometry, the balanced fertilization is another important factor. Nitrogen is the most deficient element especially in coarse textured sandy soils of Rajasthan (Arkery *et al.*, 1956). Availability of nitrogen is important for growing plants as it is major indispensable constituent of protein and nucleic acid. Being a part of plant hormones, it is involved in regulating plant growth and development. An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally leading to higher productivity. The application of nitrogen with different doses increased plant growth and yield of onion (Patel *et al.*, 1992 and Sharma, 1992).

Phosphorus is indispensible constituent of nucleic acids, phospholipids and several enzymes. It is also needed for the transfer of energy within the plant system and is involved in its various metabolic activities. Phosphorus has its beneficial effect on early root development, plant growth, yield and quality.

Potassium play an important role in crop productivity. It functions as an activator of numerous enzymes like pyruvic kinase, cytoplasmic enzymes and therefore, cause pervasive effect on metabolic events. It is always involved in the movement of carbohydrates and soluble nitrogen compounds point to diminish protein synthesis in K deficiency. There are also evidences of direct involvement of potassium in photosynthesis through its relation with chloroplast, where it is highly concentrated in leaf tissues. Metabolic activities of chloroplast are also influenced by potassium level in there organelles. Potassium activates the fat producing enzymes and enhances the oil content (Mandal and Chatterjee, 1973).

Vermicompost has been advocated as good organic manure for use in field as well as vegetable crops. Use of vermicompost as a biofertilizer and substitute for chemical fertilizer is advised by pioneers of organic farming. Earthworms are finally divided into peat like materials with high porosity, aeration, drainability and water holding capacity. They contain/provide nutrients in the readily available form to the plants such as nitrate, exchangeable phosphorus, soluble K, Ca and Mg (Edwards and Burrows, 1988). They also contain biologically active substances such as plant growth regulators (Krishnamoorthy and Vajranabhaiah, 1986; Grappolli *et al.*, 1987 and Tomati *et al.*, 1987). The application of organic manure like FYM and vermicompost alone and incombination with NPK have been reported to decrease the bulk density, improve soil porosity and increase water holding capacity (Maheswarappa *et al.*, 1999).

Integrated nutrient supply approach for the crop by judicious mixture of organic manure along with the inorganic fertilizer has a number of agronomical and environmental efficiencies. Integrated nutrient supply approach is not only the liable way for obtaining fairly high productivity with substantial fertilizer economy but a concept of ecological soundness leading to sustainable agriculture (Swaminathan, 1987). Use of vermicompost in conjunction with chemical fertilizers has been found to be promising not only in maintaining and sustaining higher productivity but also providing stability in crop production.

The information on the balanced use of chemical fertilizers alongwith vermicompost for *kharif* season onion in the state is very scare. Hence, keeping in view the facts and certain other reasons, an investigation entitled "Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv.N-53 in semi arid conditions" was conducted at Horticulture farm of SKN College of Agriculture, Jobner with the following objectives:

1. To find out the suitable crop geometry for *kharif* season onion.
2. To determine the best level of inorganic and organic fertilizer for enhancing the growth, yield and quality of onion.
3. To find out the best combination of crop geometry and fertilizer level.
4. To anlayse the benefit cost ratio for treatments.

2. REVIEW OF LITERATURE

The literature relevant to the "Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa)* cv. N-53 in semi arid condition is presented in this chapter. Some references of other crops have been also incorporated.

2.1 Effect of crop geometry on growth, yield and quality of onion

Das *et al.* (1972) conducted an experiment in which onion were planted at spacings of 8 x 20, 12 x 20 and 16 x 20 cm and fertilized with nitrogen 40, 80, 120 or 180 kg ha^{-1} and observed that yields were greatest at the former closer spacings and the 2 latter highest doses of nitrogen.

Singh (1972) conducted an experiment on onion cv. Pusa Red with 3 nitrogen levels (70, 90 and 110 kg ha^{-1}) and 3 spacings (10 x 30, 20 x 30 and 30 x 30 cm). The N x spacings interaction was significant for bulb size and yield. Nitrogen 70 kg ha^{-1} and 30 x 30 cm spacing gave the biggest bulbs and N 90 kg ha^{-1} and 30 x 10 cm spacing produced maximum yield ha^{-1}.

Verma *et al.* (1972) conducted an experiment with four levels of nitrogen (0, 200, 400 and 600 kg ha^{-1}) and four spacing between plants (6, 9, 12 and 15 cm) with a constant row spacing of 15 cm. They concluded that for profitable crop of onion the seedling should be planted at 9 x 15 cm apart and supplied with 200 kg nitrogen (half organic + half inorganic) and 50 kg P_2O_5 ha^{-1} under Agra condition.

Eunus *et al.* (1974) recorded maximum yield of bulbs and bulbs with shoot, when plants were spaced at 5 cm apart and differed significantly as compared to 10, 15 and 15 cm spacing.

Grinberg (1976) recommended that every m of row (with 45 cm space between rows) 30-40 bulbs (< 1 cm in diameter), 22-26 bulbs (1.1 –1.5 cm in diameter) and 18-20 bulbs (1.6-2.0 cm in diameter) may be planted for better results.

Rashid and Rashid (1976) while conducting a trial with local onion cv. 'Unspecified' and keeping plant spacing by transplanting from 8 x 4 to 12 x 6 inches in a single row system and from 4 x 4 to 6 x 6 inches in multiple row system obtained highest yield acre-1 (13108.04 ib) with 4 x 4 inches spacing without an appreciable decrease in bulb size.

Badaruddin and Haque (1977) found with the closest spacing gave the highest onion yield 11058 and 11515 lbs/acre for 1st and 16th Dec., when the row spacing of 12 inches and plant spacing of 4, 6 and 8 inches were planted.

Mangual *et al.* (1979) studied five row spacings *viz*., 30, 38, 45, 60 and 90 cm and two doses of each of N, P_2O_5 and K_2O i.e. 111 or 222 kg^{-1} at 2 localities. They recorded maximum yield of onion bulbs (27.89 t ha^{-1}) with 111 kg ha^{-1} NPK each and 30 cm row spacing.

Anez and Tavira (1986) conducted an experiment with the combination of N, P_2O_5 and K_2O (each 120 kg ha^{-1}) which were applied to seedlings of cv. Texas Early Grano 502 planted 10 cm apart with inter row spacings of 20-80 cm. Yields were highest (121.7 t ha^{-1}) with inter row spacings of 20-23 cm in combinations of P_2O_5 and K_2O without N application.

Khushi *et al.* (1990) transplanted one month old seedlings of onion cv. Phulkara at 3 inter (20, 30 and 40 cm) and 3 intra (10, 15 and 20 cm) row spacing. Wider inter and intra-row spacing resulted in significant increase in number of leaves $plant^{-1}$, plant height and single bulb weight. The highest bulb yield (13.10 kg/m^2 plot) was obtained at an inter x intra row spacing of 20 x 10 cm.

Rahim *et al.* (1992) reported that the combination of the highest application rate of N and K resulted in yield 11.11 t ha^{-1} compared with 4.5 t ha^{-1} from unfertilized control plots. He further reported that the highest yield were obtained from the largest set with paclobutrazol and closest spacing.

Singh (1995) reported that number of marketable bulbs and yield of onion cv. Arka Niketa were higher at the closet spacing (15 x 7.5 cm) than at the widest spacing, however, bulb size was greater at the widest spacing (15 x 12.5 cm).

Srivastava *et al.* (1995) reported that sulphur content (%) in bulb of onion var. N-53 was highest with 10 x 10 cm row spacing while chlorophyll content in leaves at 105 days after transplanting was maximum with 15 x 10 cm row spacing.

Ahmdi *et al.* (1996) recorded highest bulb yield (56.97 q ha^{-1}) when crop was planted on 22nd Oct, at the spacing of 20 cm between rows. The author studied 6 planting dates (i.e. 7th Oct to 21st December at 15 days interval and 4 planting distances i.e., (20, 30, 40 and 50 cm between rows).

Mehla *et al.* (1996) recorded highest bulb yield of onion when cv. Agri Found Light Red was spaced 10 cm apart between rows and fertilized with 120 kg N ha^{-1}.

Kumar *et al.* (1998) reported that 20 x 20 cm spacing was best with regard to plant height, length and diameter of longest leaf, thickness of stem, number of leaves $plant^{-1}$, bulb diameter and fresh weight and dry weight of onion, when seedlings were spaced at 20 x 10 cm, 20 x 15 cm and 20 x 20 cm. However, the highest bulb yield was obtained when the plants were spaced at 20 x 10 cm.

Singh and Sachan (1998) conducted the an experiment on three spacing combinations i.e., 30 x 15 cm, 30 x 30 cm and 30 x 45 cm and

3 bulb diameters on onion cv. Kalyanpur Round Red. It was observed that wider spacing and larger size resulted in more plant height and number of leaves $plant^{-1}$.

5. Sharma and Babel (1999) recorded higher yield and better quality bulbs when kharif season crop was planted at a spacing of 45 x 10 cm.
6. Anonymous (2000) recommended that for *kharif* season onion, when planting was done at 45 x 10 cm spacing, yielded maximum.
7. Jha *et al.* (2000) conducted an experiment with four levels of phosphorus (0, 25, 50 and 75 kg ha^{-1}) on 3 varieties of onion *viz*., Pusa Red, Pusa White Flate and Pusa Madhvi. They found that all the growth parameters showed a linear enhancement with the increased phosphorus dose. In general, phosphorus @ 50 kg P_2O_5 ha^{-1} was found to improve fresh/ dry matter yield. Phosphorus uptake declined beyond 50 kg P_2O_5 ha^{-1}, however, uptake increased almost four fold in later stages of crop growth.
8. Naik and Hosamani (2000) studied the effect of different spacings (15 x 10 cm, 15 x 15 cm and 15 x 20 cm) with four levels of nitrogen i.e., 0, 50, 100 and 150 kg ha^{-1} with P_2O_5 and K_2O 50 and 100 kg ha^{-1} as constant. They found that 15 x 10 cm spacing with the application of nitrogen 150 kg ha^{-1} resulted in maximum plant height, number of leaves, bulb length, bulb diameter and yield per hectare (189-60 q).
9. Jejurkar *et al.* (2000) reported that number of functional leaves, average neck thickness, equatorial diameter and average weight of bulbs in onion were maximum with wider spacing i.e., 15 x 20 cm as compared to lower spacing. However, average polar diameter and yield of small bulbs were significantly reduced with wider spacing.
10. Kumar *et al* (2001) reported that the highest bulb yield during 1992-93 and 1993-94 (279.72 and 273.43 q ha^{-1}, respectively) were obtained with 20 x 20 cm spacing. They also reported that growth parameters and bulb characters were better in the 20 X 20cm spacing as compared to narrower spacing densities (20 X 10 and 20 X 15 cm).

11. Panda and Mohanty (2001) conducted that plant height and yield were increased with narrow spacing while the number of leaves and bulblets per plant and weight of bulb per clump significantly decreased compared to wider spacing.
12. Sharma and Koul (2002) reported that widest plant spacing (45 x 15 cm) gave maximum per plant yield (156 g) in leek but the overall ha^{-1} yield was low (197.5 q ha^{-1}) whereas, the maximum yield (287 q ha^{-1}) was recorded with plant spacing of 30 x 15 cm when leek were planted at different spacing *viz*., 30 x10, 30 x15, 30 x 20, 45 x 10, 45 x 15cm during 3 consecutive years.

13.2.2 Effect of N, P and K on growth, yield and quality of onion

14. Singh *et al.* (1972) obtained the maximum bulb size and yield with a combination of 112 : 56 : 28 kg ha^{-1} of N : P_2O_5 : K_2O when they conducted an experiment in onion on sandy loam soil with three levels of nitrogen (56, 112 and 168 $kgha^{-1}$), two levels of phosphorus (28 and 56 kg ha^{-1}) and two levels of potassium (0 and 28 kg ha^{-1}).
15. Bhuiya *et al.* (1974) conducted a trial on onion with 2 levels of each nitrogen (0 and 56 kg ha^{-1}), phosphate (no phosphate and 56 kg ha^{-1}) and potash (no potash and 56 kg ha^{-1}) in the non calcareous dary grey flood plain and observed that the application of N, P and K significantly increased the yield.
16. Pandey *et al.* (1982) conducted a trial on plant spacings of 20, 30 or 30 cm in row and 45 cm inter row distance with N levels of 20, 40 or 60 kg ha^{-1} and obtained 14.7-15.2 q ha^{-1} seed yield with 40 or 60 kg N ha^{-1}.
17. Madan and Saimbhi (1984) conducted trial with Punjab-48 onion cultivar and planted at a distance of 30 or 45 cm between rows and obtained the seed yield 10, 12.3 and 11 q ha^{-1} on plots receiving 100, 150 and 200 kg N ha^{-1} respectively.

18. Lal *et al.* (1988) applied different nutrients viz., N, P, K (60 : 60 : 30 kg ha^{-1}), pyrite 100 kg ha^{-1} and $ZnSO_4$ or $FeSO_4$ both 25 or 50 kg ha^{-1} through soil application. $FeSO_4$ 50 kg ha^{-1} significantly increased N, P and K content in the leaf and bulb, whereas, $ZnSO_4$ had an adverse effect on P and K uptake in onion crop.

19. Shukla *et al.* (1989) treated onion cv. Nasik Red with N @ 0, 75 and 150 kg ha^{-1} and P_2O_5 @ 0 or 60 kg ha^{-1}. The highest yield was recorded with N and P levels but benefit : cost ratio was optimal with N at 75 kg ha^{-1}.

20. Shanthi and Balakrishnan (1989) obtained the highest yield, best bulb quality and highest nutrient uptake, when var. MDU-1 was planted 45 x 45 cm apart, fertilized with 90 kg N ha^{-1} and sprayed with MH 2000 ppm.

21. Duque *et al.* (1989) reported that N and K requirement for onion crop was high during early growth stages, whereas P requirement was continuous throughout the development. Uptake levels were 38.8, 38.6 and 71.3 kg ha^{-1}, N, P_2O_5 and K_2O, respectively for a yield of 2.5 t ha^{-1}.

22. Bhatia and Pandey (1989) applied nutrients in different combinations viz., N, P, K (50+20+10, 100 + 40 + 15 and 150 + 60 + 20 kg ha^{-1}) in onion crop. The highest plant height (73.7 cm) and number of leaves $plant^{-1}$ (39.7) were obtained with the combination 150 + 60 + 20 kg ha^{-1}.

23. Pandey *et al.* (1991) obtained the maximum yield and net return of onion crop with the application of NPK 150 : 40 : 50 kg ha^{-1}.

24. Baloch *et al.* (1991) obtained highest bulb yield (22.66 t ha^{-1}) in onion with 125 kg N + 125 kg K_2O ha^{-1} application, while maximum plant height (38.5 cm), number of leaves $plant^{-1}$ (17.0), single bulb weight (82 g), vertical bulb diameter (4.80 cm) and bulb diameter (5.78 cm) was obtained with 125 kg N + 100 kg K_2O ha^{-1}. The variety

used was phulkara and it is seedlings planted at 20 cm were inter row spacing and 8 cm intra row spacing.

25. Pimpini *et al.* (1992) stated that combined application of fertilizers (140 kg N + 140 kg P_2O_5 + 100 kg K_2O ha^{-1}) to onion crop gave larger sized onion bulbs.

26. Katwale and Saraf (1994) recorded highest bulb yield and return when cv. N-53 was fertilized with NPK rate of 125 : 60 : 100 kg ha^{-1}.

27. Mallangouda *et al.* (1995) recorded the highest yield (4698.38 kg ha^{-1}) and the highest uptake of NPK (186.32, 24.69 and 102.09 kg ha^{-1}) respectively with the application of.

28. Warade *et al.* (1995) obtained the maximum bulb yield (27.7 t ha^{-1}) of onion with 40 t FYM + NPK (100 : 50 : 50 kg ha^{-1}).

29. Singh *et al.* (1997) obtained highest gross yield (323.1 q ha^{-1}), marketable yield (313.6 q ha^{-1}) and net return with the application of 100 kg N + 25 kg P+ 25 kg K ha^{-1} to onion crop.

30. Singh *et al.* (2000) found that fertility levels contributed significant improvement with regard to height and number of $plant^{-1}$. The maximum height and number of levels of cv. Agri Found Dark Red were recorded with the application of medium fertility levels i.e., 200+ 80 + 120 kg NPK ha^{-1} in *kharif* season crop.

31. Prakash *et al.* (2000) revealed that increasing levels of nitrogen (0 to 150 kg ha^{-1}) and FYM (0 to 20 t ha^{-1}) brought marked improvement in bulb yield, yield attributes and TSS. The highest bulb yield (461.6 q ha^{-1}), bulb weight (105 g), bulb diameter (5.9 cm) and TSS (10.4 %) in onion were recorded with the nitrogen level 150 kg ha^{-1}. Application of 150 kg N + FYM 20 t ha^{-1} registered highest gross return (Rs 195707.00).

32. Sharma and Paliwal (2000) recommended that for successful onion cultivation, onion should be applied with 100: 50: 100 kg NPK ha-1 respectively. Singh (2001) reported that application of 150 kg N + 60

kg K_2O ha^{-1} significantly improved the plant height, number of leaves $plant^{-1}$, neck thickness and bulb yield of onion.

33. Singh *et al*. (2001) reported that average weight / bulb and bulb yield increased significantly, when N at 120 kg ha^{-1} and FYM at 10 t ha^{-1} applied in rainy season onion. However, the maximum net returns and benefit : cost ratio were recorded with N application @ 150 kg ha^{-1} and farmyard manure application @ 10 t ha^{-1} when the bulb yield was described as quadratic function of N x F, a combination of 148.88 kg N + 9.13 t FYM ha^{-1} cultivation was found to be an optimum requirement of N and FYM for maximizing returns.

34. 2.3 Effect of NPK and plant spacing on growth, yield and quality of onion

35. Randhawa and Singh (1974) conducted an experiment to find out the optimum spacing and N, P and K requirements for onion crop var. Punjab Selection. It was found that plants took maximum number of days (131.60) to mature under the influence of N (150 kg ha^{-1}) as compared to N (75 kg ha^{-1}) and control which were at par among themselves. Closer spacing of 15 x 10 cm produced maximum number of bulbs and total bulb yield (116.96 q ha^{-1}) than wider spacing the yield was also increased with an increase in the dose of nitrogen. The application of N (150 kg and 75 kg ha^{-1}) being at par with each other gave highest bulb yield of 127.88 and 144.66 q ha^{-1} respectively. The effect of P, K and various interaction of N, P and K with different spacing was non significant in increasing the yield.

36. **Setty *et al.* (1989) carried out a field experiment comprised of three levels of N (0, 100 and 200 kg ha^{-1}), P_2O_5 (0, 50 and 100 kg ha^{-1}) and K_2O (0, 50 and 100 kg ha^{-1}). The maximum bulb diameter (3.67 cm) and the highest yield (7.91 t ha^{-1}) was recorded with 100 kg N + 50 kg P_2O_5 and 50 kg K_2O ha^{-1}**

37. Jana *et al.* (1990) obtained the higher plant height (48.62 cm), number of leaves (9.14), bulb diameter (6.13 cm), weight of 10 bulbs (1.02 kg) and yield (30.69 t ha^{-1}) with 30 kg S ha^{-1} application, when sulphur powder was applied @ 0, 30, 40 or 50 kg ha^{-1}.

38. Pandey and Ekpo (1991) obtained highest bulb yield (460.2 q ha^{-1}) and bulb weight (197.8 g) by application of 160 kg N ha^{-1}, when onion cv. Bana Local received 0, 40, 80, 120 and 160 kg N kg ha^{-1}.

39. Pandey *et al.* (1991) studied the response of different levels of N, P and K on yield and quality of *kharif* onion cv. N-53. The treatments comprised of four levels of N *viz.*, 0, 50, 100 and 150 kg ha^{-1}, three levels of P_2O_5 viz., 0, 40 and 80 kg ha^{-1} and two levels of K *viz.*, 0 and 50 kg ha-

^{1} alone and incombination. The maximum yield and net returns were achieved with N : P : K at the rate of 150 : 40 : 50 kg ha^{-1}, however P and K alone had no effect on bulb diameter, neck thickness, TSS and yield.

40. Sharma (1992) conducted an experiment on sandy loam soil; sets or seedlings of onion cv. N-53 were planted at an spacing of 15 x 10 cm. Nitrogen was applied in 3 equal split doses of 0, 50 or 100 kg ha^{-1} and potash was applied at planting 0, 40 or 80 kg ha^{-1}. It was found that bulb yield and green leaf yield were higher from sets (33.8 t ha^{-1}) than from seedlings (27.7 t ha^{-1}). Bulb yield was significantly higher with 50 kg N ha^{-1} than with no N in all the years. Application of 40 kg ha^{-1} significantly increased yield but 80 kg K ha^{-1} had no effect further.

41. Rajas *et al.* (1993) obtained better 'S' content (65 mg/100g) and higher number of dry bulbs with the combination of 80 kg S ha^{-1}, spaced at 20 x 15 cm and irrigated at an interval of 5 days, when onion cv. Pusa Red were applied with S @ 10, 40, 60 or 80 kg ha^{-1}, spaced at 10 x 15, 15 x 15 and 20 x 15 cm and irrigated at an interval of 5, 10 or 15 days.

42. Rizk (1997) studied the effect of plant density (2 or 3 lines/ridges) and NPK fertilizers (4 rates and 2 methods of application) on the productivity of onion and found that lower planting densities resulted in higher number of leaves plant^{-1}, higher fresh and dry weight, leaf area, higher average bulb weights and higher uptake of N.

43. Gupta and Sharma (2000) conducted the trial on different plant spacing *viz.*, 10 x 5, S_1; 10 x 7.5, S_2 and 10 x 10cm ; S_3 and 3 NPK rates *viz.*, 75: 50: 50, 100: 5:50 and 125: 50 :50 kg ha^{-1} on onion cv. Agri Found Light Red. They recorded that S_1 had the thinnest neck bulb. Although plant height, leaf number, bulb diameter were highest in S_3 spacing but gross and marketable yields were highest in $S_1$by virtue of highest plant population.

44. Muthuramalingam *et al.* (2002) observed that the closer spacings of 45 x 5 cm recorded the maximum uptake of N, P and K; when experiment were conducted in three spacings *viz.* 45 x 5 cm, 45 x 10 and 45 x 15 cm and 10 combinations involving three levels of N (20, 40 and 60 kg ha^{-1}) , three levels of P (20, 40 and 60 kg ha^{-1}) and a constant level of K (30 kg ha^{-1}) along with FYM at 25 t ha^{-1}.

45. Yadav *et al.* (2002) concluded that application of 100 kg N and 150 kg K_2O ha^{-1} was ideal for obtaining higher bulb production of *kharif* onion when sets were planted 22.5 X 10 cm spacing in semi arid condition of Rajasthan.

46. Naik and Hosamani (2003) conducted a field experiment to investigation the effect of different spacings (15 x 10, 15 x 15 and 15 x 20 cm) and N levels (0, 50, 100 and 150 kg ha^{-1}) on growth and yield of *kharif* onion under rainfed condition of Dharward and of Karnataka. They found that narrow spacing of 15 x 10 cm with application for enhancing yield (169.02q ha^{-1}) and other growth quality parameters

such as plant height, leaf number per plant, bulb length, bulb diameter and total suitable solid content The maximum net return and benefit :cost ratio were also recorded from this treatment combination.

47. 2.4 Effect of N, P, K and vermicompost on growth yield and quality of onion

48. **Singh *et al.* (1997) conducted an experiment to determine the effect of different organic manures and inorganic fertilizers on the yield of quality of *rabi* onion cv. Agri Found Dark Red. The organic manure used were green manure, farm yard manure (25 t ha^{-1}) and vermicompost (2 t ha^{-1}). The inorganic fertilizers were 100 kg N, 100 kg N + 50 kg P, 100 kg N + 25 kg P + 25 kg K and 100 kg N + 50 kg P + 50 kg K ha^{-1}, when FYM was combined with 100 kg N + 25 kg P + 25 kg K ha^{-1}, gross and marketable yield was increased to 323.1 and 313.6 q ha^{-1} respectively and the highest net return of Rs 32651 ha^{-1} was obtained.**

49. **Thanunathan *et al.* (1997) conducted a pot experiment on onion grown in 12 different combinations of soil, mine soil, vermicompost made from coir or water hyacinth '*Eichhornia crassipes*" and FYM. It was concluded that organic amendments increased onion growth and yield in mine spoil while coir vermicompost was appeared to be a very effective amendment for that purpose.**

50. **Ahmed and Reddy (2000) conducted an experiment to develop soil test based fertilizer recommended with or without use of organic manure i.e., FYM or vermicompost. The experiment field consisted of four blocks, out of which one block received inorganic fertilizer alone, 2^{nd} and 4^{th} block received 5 and 10 t ha^{-1} of FYM, respectively and 4^{th} block received 2 t ha^{-1} of vermicompost in addition to inorganic fertilizers. Each block was divided into 20 sub plots with 19 selected treatments consisting of three levels of N (0, 30, 60, 90 kg ha^{-1}), P_2O_5 (0, 40, 80 kg ha^{-1}) and K_2O (0, 60. 120 kg ha^{-1}) and one control was maintained without use of inorganic fertilizers. It was found that bulb yield positively and significantly correlated with plant uptake of nutrients. It had positive and significant relation with inorganic fertilizers, in conjunction with organic manure and soil nutrients (N, P and K).**

51. **Chaurasia *et al.* (2000) recorded maximum average bulb weight (665.6 g), bulb size (253.8 cm^2) and yield (3632.5 q ha^{-1}) when onion cv. Agri Found Light Red was treated with press mud @ 10 t ha^{-1} followed by FYM @ 20 t ha^{-1}. The effect of application of treated sevage sludge @ 10 t ha^{-1} on yield parameter was recorded to be statistically at par with the application of NPK @ 100 : 60 : 80 kg ha^{-1}.**

52. **Yadav *et al.* (2001a) obtained the maximum head yield (207.48 q ha^{-1}), head weight (426 g), head diameter (10.87 cm), marketable head per plot (45.27), plant spread (33.03 cm) in cabbage with the treatment NICAST 500 kg ha^{-1} + recommended dose of N:P:K i.e, 150 : 80 : 75 kg ha^{-1} which was at par with the treatment (recommended dose of FYM**

i.e., 25 t ha^{-1} + recommended dose of N:P:K) and NICAST 750 kg ha^{-1} + recommended dose of N:P:K i.e., 180 : 80 : 75 kg ha^{-1}.

53. **Yadav *et al.* (2001b) revealed that the treatment recommended dose of FYM (30 t ha^{-1}) + recommended N:P:K (100 : 50 : 100 kg ha^{-1}) give significantly higher bulb yield (370.37 q ha^{-1}), however it was at par with the treatment NICAST 750 kg ha^{-1} + recommended dose of N:P:K (100 :50 : 100 kg ha^{-1}) recording 367.41 q ha^{-1} bulb yield with maximum net return (Rs 47132.0) and highest B:C ratio (2.79 : 1) when onion cv. RO-1 were applied with the combination of recommended doses of FYM, NICAST 250, 500 and 750 kg ha^{-1} NPK with or with out recommended doses of fertilizers and vermicompost (15 t ha^{-1}).**

54. **Padmavathi *et al.* (2002) recorded the highest average fruit weight of tomato in plants supplied with a combination of FYM + 50 per cent recommended dose of inorganic fertilizers followed by application of 50 per cent recommended dose of vermicompost + 50 per cent inorganic fertilizer.**

55. 2.5 Effect of NPK and vermicompost on growth, yield on other crops

56. Kalambaso (1996) reported that vermicompost @ 15 kg m^{-2} gave highest yield in tomato crop.

57. Patil *et al.* (1997) reported that total number of yield of tubers of potato was significantly higher with the application of vermicompost (4 t ha^{-1}) than FYM (25 t ha^{-1}).

58. Singh *et al.* (1997) reported that application of vermicompost @ 10 t ha^{-1} increased the microbial activities, had shown its positive effect on the performance of the plant as indicated by higher number of branches and fruits.

59. Mahendran and Kumar (1997) obtained the highest TSS and ascorbic acid contents by applying 75 per cent of the recommended rate of NPK combined with digested organic supplements (dors) and vermicompost. Polar and equatorial diameter of cabbage heads and net weight were also significantly influenced by applying organic manures.

60. Patil *et al.* (1998) recorded highest net income (Rs 28970), highest increase of net income (24.18%) over recommended dose of fertilizer and high cost: benefit ratio (1 : 347) in the treatment recommended dose of fertilizer + 50% vermicompost in tomato crop.

61. Reddy *et al.* (1998) reported that pod per plant, seed per pod and yield was significantly higher with the application of 10 t ha^{-1} vermicompost + recommended dose of NPK (27.5 : 60 : 50 kg ha^{-1}) in garden pea cv. Sel. FC-1.

62. Sharhidhara *et al.* (1998) reported that application of 100 per cent recommended dose of NPK (150 : 75 : 75 kg ha^{-1}) together with 2.5 t ha^{-1} vermicompost increased dry pod yield significantly over 50 per cent and 0 per cent recommended dose of fertilizer in chilli.

63. Atiyeh *et al.* (1999) observed that when 20 per cent commercial horticultural medium was replaced by vermicompost there was significant increase in plant height and root and shoot biomass in tomato crop.

64. Kumari *et al.* (1999) reported that 12 t ha^{-1} vermicompost + full dose of recommended fertilizer (50 : 8 : 25 kg NPK ha^{-1}) produced highest yield and vermicompost as an organic source significantly reduced the cost of okra production.

65. Sreenivas *et al.* (2000) conducted an experiment on ridge gourd to study the effect of integrated nutrient supply. There were four levels of each of fertilizer (0, 25, 50 and 100% of recommended dose of N, P_2O_5 and K_2O) and vermicompost (0, 5, 10 and 15 t ha^{-1}). Application of vermicompost at the rate of 10 t ha^{-1} plus 50 : 25 : 25 kg ha^{-1} N, P_2O_5 and K_2O fertilizer was found best to achieve maximum yield with better quality fruits.

66. Rajkhowa *et al.* (2000) found that 75% recommended dose of nitrogen as urea + 5 t ha^{-1} vermicompost application increased N, P, K percentage in plant in green gram cv. ML-131.

67. Patil *et al.* (2002) concluded that the highest bulb yield of 16.26 t ha^{-1} was obtained in the treatment of 100 per cent recommended dose (125: 50: 125 NPK kg ha^{-1}) of fertilizer RDF and FYM (30 t ha^{-1}) followed by vermicompost (1 t ha^{-1}) plus 50 per cent RDF (15.70 t ha^{-1}) and 50 RDF per cent plus ACD- 20 stain of Azospirillium (15.38

t ha^{-1}). But maximum net profit of Rs 37,881 and cost benefit ratio of 1:4.59 were recorded in the treatment of 50 RDF plus ACD- 20 followed by the treatment vermicompost 1 t ha^{-1} plus 50 per cent RDF (Rs 37,749 & 1: 4.05).

68. Yadav and Luthra (2002) performed an experiment on water melon to evaluate the suitable combination of organic manure and recommended dose of fertilizers for higher yield and recorded the maximum fruit yield (355.55 q ha^{-1}), average fruit weight (4.48 kg), dry matter (8.11 %), with treatment of NICAST @ 500 kg ha^{-1} + recommended N: P: K, which was at par with the treatment of (recommended FYM @ 20 t ha^{-1} + recommended N: P: K) and (recommended vermicompost @ 10 t ha^{-1} + recommended N: P: K). The maximum net return of Rs 40,.840.84 with highest benefit cost ratio 2.93) was obtained under the treatment of NICAST @ 500 kg ha^{-1} + recommended N: P:K.

69. Narayanamma *et al.* (2004) conducted an experiment to find out the effect of different organic manures (FYM @ 20 t ha^{-1}, vermicompost @ 4 t ha^{-1}, neemcake @ 2 t ha^{-1}) and their combinations were compared with recommended dose of fertilizer (RDF- 50: 40: 50 kg NPK ha^{-1}) on the carrot production. The results indicated that yield obtained with the application of organic manure and their combinations (18.3 to 20 t ha^{-1}) were comparable with that of yield obtained with recommended dose of fertilizer (17.4 t ha^{-1}) but significantly higher when compared to the control (15 t ha^{-1}).

70. Raghav *et al.* (2004) obtained the highest tuber yield of Kufari Pukharaj with 75 % recommended dose of fertilizers with 10 t of FYM, where as Kufari Sutlaj and Kufari Badshah gave better yield at 100 and 125 % RDF along with 10 t FYM respectively. There was very little or/ no response of increased fertility levels on the tuber yield of cultivars.

71. Yadav and Luthra (2004) observed that NICAST @ 500 kg ha^{-1} and vermicompost @ 15 t ha^{-1} with recommended dose of N:P:K gave at par green pod yield as compare to FYM @ 20 t ha^{-1} with recommended dose of N:P:K (25 : 40: 50 kg ha^{-1}). The maximum green pod yield (127.40 q ha^{-1}) with maximum net return ha^{-1} (Rs 40760) and highest B: C ratio (2.77) was obtained under the treatment NICAST @ 500 kg ha^{-1} + recommended dose of N:P:K.

72. On the basis of this review of literature it was concluded that on one hand a vast body of knowledge has been generated on the effect of crop geometry on onion. Similarly the information generated on fertility levels specially use of vermicompost in *kharif* onion is very meagre. The *kharif* onion is an important bulb crop and the use of fertility levels specially vermicompost along with different crop geometry appear to be the victims of considerable. Therefore, the present investigation is justifiably believed to accommodate these gaps.

3. MATERIALS AND METHODS

The field experiment entitled "Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions" was conducted during *kharif* season for two years i.e., 2001-02 and 2002-03. The experimental materials and criteria used for treatment evaluation during the course of investigation are being presented in this chapter.

3.1 Experimental site

The experiment was laid out at Horticulture farm, SKN College of Agriculture, Rajasthan Agricultural University, Jobner during "*kharif*" seasons of 2001 and 2002. Jobner is situated at 26.05^0 North latitude, 75.20^0 East longitude and an altitude of 427 meters above mean sea level, in Jaipur district of Rajasthan. This region falls under agroclimatic zone III-A (Semi-Arid Eastern Plain) of the state.

3.2 Climate and weather

The climate of Jobner is typically semi-arid characterized by extremes of temperature both in summer and winter with low rainfall and moderate relative humidity. Maximum temperature in summer is as high as 47^0 (sometimes) and minimum temperature in winters falls around 0^0 C. The average rainfall of the locality is approximately 500 mm; most of which is received in rainy season from July to September. Yearly pan evaporation ranges from 1.3-17.5 mm. Since climatic conditions influence growth, yield and quality of agricultural produce, therefore, the mean weekly weather parameters for the crop growing seasons recorded at meteorological observatory , Jobner are presented in Table 3.1 and are graphically depicted in Fig.3.1 and 3.2.

3.3 Soil characteristics of the experimental field

To ascertain physico-chemical characteristics of the soil during both the years of experimentation, soil samples from 0-15 cm depth were collected from different locations of the experimental field before application of fertilizer. A representative composite sample was prepared by processing and mixing them together and then analysed for physical and chemical characteristics. The results of analysis presented in Table 3.2 showed that the soil was loamy sand in texture, slightly alkaline in reaction, poor in organic carbon with low available nitrogen, phosphorus and sulphur and medium in potassium content.

3.4 Treatment details and experimental design

The experiment was comprised of 32 treatment combinations with four spacings and eight levels of fertilizers related to recommended dose alongwith vermicompost. These treatments with their symbols are given in Table 3.4.

3.4.1 Design and layout of experiment

The experiment was laid out in split-plot design with spacing in main plot and combination of recommended doses of NPK levels and vermicompost at the rate of 2.5 t ha^{-1} in sub plots, having 4 replications in both the years. The treatments were randomly allotted to different plots using random number of table of Fishers and Yates (1963). The layout of experiment with allocation of treatments and other details of the experiments is shown in Fig. 3.3.

The details of layout are as under.

1.	Design of experiment	:	Split-plot design
2.	Total number of treatment combinations	:	32
3.	Replications	:	4
4.	Total number of plots	:	128
5.	Plot size	:	1.8 x 2.4 m = 4.32 Sq. m
6.	Name of crop	:	Onion
7.	Net experimental area	:	552.96 Sq. m
8.	Total area	:	659.12 Sq. m

3.5 Raising of the experimental crop

The schedules of different pre and post-sowing operations carried out during the two crop seasons and details of crop raising are described as under.

3.5.1 Field preparation

The experimental field was thoroughly ploughed and cross ploughed with the help of mould board plough and cross harrowing was done with tractor. Planking was followed after this and soil was brought to a good tilth (practice followed for both the years were similar). Beds of 1.8 x 2.4m size were prepared, paths and channels were also prepared as per layout. Then in beds 4 and 6 ridges were prepared as per the treatments of spacing. In the crop spacing treatments of 30 x 10 cm and 30 x 15 cm 6 ridges of 20 to 30 cm height were prepared and in 45 x 10 cm and 45 x 15 cm crop geometry 4 ridges of 20-30 cm height were prepared.

3.5.2 Preparation of onion sets

To obtain good quality of onion sets, the seeds at the rate of 10 kg ha^{-1} was sown in well prepared nursery bed of 200 sq. m area in the first week of February. The seed of variety N-53 was used, for getting smaller size onion (1.5 to 2.0 cm diameter set), the seeds were sown at a closer spacing. Then sets were lifted in the first week of May from the nursery beds, tops were removed and sets were graded. Then the sets were stored in gunny (cloth) bags for further transplanting in the season.

3.5.3 Treatment application

3.5.3.1 Vermicompost : The vermicompost was applied at the rate of 2.5 tonnes ha^{-1} and spread uniformly below and around the ridges. For the bed size of 4.32 sqm its quantity was calculated and applied before the planting of onion sets but after laying out the field.

3.5.3.2 NPK application: In the experiment the source of nitrogen, phosphorus and potassium were urea, single super phosphate and muriate of potash.

The recommended dose of NPK for onion crop was 100:50:100 kg ha^{-1}. For each fertilizer treatment combinations the NPK doses were calculated and applied timely. For example, in the treatment of 100 per cent recommended dose of NPK means N 100 kg ha^{-1}, P_2O_5 50 kg ha^{-1} and K_2O 100 kg ha^{-1} and in the treatment of 125% recommended dose of NPK the fertilizers were applied at the rate of N 125 kg ha^{-1}, P_2O_5 62.5 kg ha^{-1} and K_2O 125 kg ha^{-1}, respectively.

3.5.3.3 Nitrogen : The application of urea was given in two split doses. First at the time of planting of onion and remaining half dose after 30 to 40 days of planting.

3.5.3.4 Phosphorus : Phosphorus was applied through single super phosphate. Wholly as basal dose as per treatment at the time of planting.

3.5.3.5 Potassium : Potassium was applied through muriate of potash wholly as basal dose as per treatments.

3.5.3.6 Manure application: A basal dose of well rotten Farm Yard Manure at the rate of 300 q ha^{-1} was incorporated in the soil at the time of field preparation.

3.6 Planting of onion in the field

The uniform size of about 1.5 – 2.0 cm diameter onion sets of N-53 were procured and they were treated with Bavistin at the rate of 1 g/kg of onion set. Then these treated sets were placed in shade for half an hour and were planted in the field. These sets were planted on both the sides of the ridges at a distance of 10 and 15 cm as per the treatment of spacing.

3.6.1 Weeding and hoeing

Onion is a shallow rooted crop, so shallow hoeing was done after 20 to 25 days and 40 to 45 days of planting. Besides this hand weeding was also done as per requirement.

3.6.2 Plant protection measures

To protect the crop from blight and purple blotch the crop was sprayed with Diathane M-45 at the rate of 0.25 per cent at 15 days interval while for the onion thrips, the crop was sprayed with malathion at the rate of 0.1 per cent 3 times at 15 days interval starting from planting.

3.6.3 Harvesting

Harvesting was done manually by hand digger. The observation on different bulb parameters were recorded after proper curing. Then the bulbs were graded as 'A' 'B' and 'C' and sold in the market.

3.7 Treatment evaluation

(A) Growth attributes

(i) Plant height (cm)

Ten plants were randomly selected in each plot and tagged. The plant height was measured from the ground level to the top of the highest leaf at harvesting.

(ii) Number of leaves per plant

Total number of leaves were counted from randomly selected plants to compute the mean number of leaves per plant.

(iii) Fresh weight of leaves at harvest

Fresh weight of leaves was recorded at the time of harvesting and average weight of leaves per plant was calculated.

(iv) Dry weight of leaves

Dry weight of leaves was recorded with the help of double pan balance after oven drying at 65 ^{0}C at constant weight.

(B) Yield attributes and yield

(i) Neck thickness (cm)

At harvesting, the neck thickness of bulb was measured with the help of vernier callipers.

(ii) Neck length (cm)

At harvest, before separating the bulb from foliage the neck length was measured with the help of meter scale.

(iii) Equatorial diameter (cm)

Equatorial diameter was measured with the help of vernier calipers at maximum width of the bulbs.

(iv) Polar diameter (cm)

Polar diameter was measured from the neck surface to the bottom root surface of the bulb with the help of vernier calipers.

(v) Number of scales/bulb

Number of scales per bulb was counted after cutting of the bulb horizontally in two halves.

(vi) Thickness of scales

The thickness of scales was measured with the help of vernier calipers of ten randomly selected bulbs and average was computed.

(vii) Fresh weight of bulb (g)

Fresh weight of ten bulbs recorded in 'grams' by weighing in double pan balance. Then average fresh weight was calculated.

(viii) Volume of bulb (cc)

Volume of onion was recorded by measuring the displaced water which was obtained by dipping the onion bulb in a measuring cylinder and average volume was calculated in cc.

(ix) Bulb yield (q ha^{-1})

Bulb yield in quintals per hectare was calculated on the basis of the total yield obtained per plot.

(C) Quality attributes

(i) Total soluble solids (%)

Total soluble solids (TSS) percentage was determined with the help of hand refractometer at the time of harvesting of bulb.

(ii) Sulphur content of bulb (%)

Sulphur was estimated by turbidometric method (Tabatabi and Bremner, 1970). Plant samples were digested with tri-acid mixture (Nitric acid, per chloric acid and hydrochloric acid) using gelatin barium chloride solution for development of turbidity. The resultant turbidity was measured by colorimeter and sulphur content was expressed in percentage on dry weight basis.

(iii) Pungency (Allyl propyl disulphide)

Allyl propyl disulphide content in onion bulb was determined as pyruvic acid (Hort and Fisher, 1971).

(iv) Vitamin 'C' content of bulb (mg/100g)

The vitamin 'C' content of bulb was determined by diluting the known volume of onion juice with 3 per cent meta-phosphoric acid and titrating with 2,6 dichloro phenol indophenol solution (A.O.A.C., 1960), till the faint pink colour was obtained.

Standardization – Standardization of the dye 2, 6-dichloro phenol-indophenol solution was done by titrating it against standard ascorbic acid solution. For this purpose, 100 mg of pure ascorbic acid was dissolved in 3 per cent meta phosphoric acid and volume was made up to 100 ml. From this 10 ml ascorbic acid solution was used for titration. The results were expressed as ascorbic acid (mg/100 g of pulp).

(v) Nitrogen content of bulb (%)

Nitrogen was estimated by digesting plant samples with sulphuric acid using hydrogen peroxide for removing black colour. Estimation of nitrogen was done by colorimeteric method using Spectronic-20 after development of colour with Nesseler's reagent (Snell and Snell, 1939). Nitrogen was calculated and expressed in percentage.

(vi) Phosphorus content (%)

Phosphorus was estimated by digesting plant sample with Tri-acid mixture of HNO_3 : H_2SO_4 : $HClO_4$ and was estimated by Vanadomolybdo phosphate yellow colour method (Jackson, 1967).

(vii) Potassium content (%)

Potassium was determined by digesting plant samples with Tri-acid mixture of HNO_3 : H_2SO_4 : $HclO_4$ and was estimated by flame photometric method (Jackson, 1967).

(D) Uptake of nutrient (N, P and K)

Uptake of nitrogen, phosphorus and potassium was computed from nitrogen, phosphorus and potassium content in bulb and leaves and yield of bulb and leaves by using the following relationship.

$$\text{Total uptake of NPK (kg ha}^{-1}\text{)} = \frac{\text{\% NPK content in bulb} \times \text{Bulb yield (kg ha}^{-1}\text{)} \times \text{\% NPK content in leaves} \times \text{Leaves yield (kg ha}^{-1}\text{)}}{100}$$

(E) Available N, P and K in soil after harvesting

The available N content in soil was determined by alkaline permanganate method (Subbiah and Asija, 1956) and available potassium was determined by extraction of soil and with 1N neutral ammonium acetate and estimated by flame photometer (Metson, 1956). The available phosphorus content in soil was estimated by Olsen method (Olsen *et al.*, 1954).

(F) Economics of treatments

The economics of treatments is the most important consideration for making any recommendation to the farmer for its wide adoption. For calculating economics, the average treatment yield along with prevailing market rates for inputs and out put were used. The net return was calculated by subtracting cost of cultivation for each treatment from gross return gained from the economic yield B:C ratio was computed by dividing gross return with cost of cultivation for each treatment. The computation details of economics for each treatment are given in Appendix-XIII.

3.8 Statistical analysis

The experimental data recorded were subjected to statistical analysis using analysis of variance technique suggested by Panse and Sukhatme

(1985). The critical differences for the treatments comparison were worked out, wherever the 'F' test was found significant at 5 per cent level of significance. To elucidate effects, summary tables along with SEm$\pm$ and critical difference is given in chapter "Experimental results" and their analysis of variance are given in the Appendices.

(B) Correlation studies

To assess inter-relationship between various characters, correlation coefficients were worked out. All these statistical estimates were done by standard statistical procedures as suggested by Panse and Sukhatme (1985).

Table 3.2 Physico-chemical characteristics of the experimental soil

S. No.	Parameters	Content 2001	Content 2002	Method adopted
A.	**Mechanical analysis**			
1.	Coarse sand (%)	27.1	26.3	International pipette method (Piper, 1950)
2.	Fine sand (%)	53.9	54.5	-do-
3.	Silt (%)	9.8	10.1	-do-
4.	Clay (%)	7.7	8.0	-do-
B.	**Physical analysis**			
1.	Field capacity (%)	10.6	11.2	Method No. 33, USDA Hand Book No. 60 (Richards, 1954)
2.	Permancut wilting point (%)	3.6	4.0	Method No. 31, USDA Hand Book No. 60 (Richards, 1954)
3.	Bulk density (Mg/m^{-3}) (0-30 cm)	1.56	1.54	Method No. 38, USDA Hand Book No. 60 (Richards, 1954)
C.	**Chemical analysis**			
1.	Organic carbon (%)	0.16	0.17	Walkely and Black rapid titration method (Piper, 1950)
2.	Available N (kg ha^{-1})	130	142	Alkaline permanganate method (Subhiah and Asija, 1956)
3.	Available P_2O_5 (kg ha^{-1})	15.2	17.0	Olsen's method (Olsen's et

				al., 1954)
4.	Available K_2O (kg ha^{-1})	140	152	Flame photometer method (Metson, 1956)
5.	Available S (ppm)	12.6	13.80	Turbidmetric method (Chesnin and Yien, 1950)
6.	ECe of saturated extract of soil at 25 ^{0}C (dSm^{-1})	1.20	1.05	Method No. 4, USDA Hand Book No. 60 (Richards, 1954)
7.	pH (1:2 soil water suspension)	8.0	8.1	Method No. 21(b), USDA Hand Book No. 60 (Richards, 1954)
D.	**Irrigation water**			
1.	EC (dSm^{-1})	1.76	1.77	Method No. 72, USDA Hand Book No. 60 (Richards, 1954)
2.	pH	8.0	8.1	Method No. 21(c), USDA Hand Book No. 60 (Richards, 1954)

Table 3.3: Composition of irrigation water used for irrigation during both the years

S. No.	Characteristics	Value	Methods followed	Reference
1	**Cations (MeL^{-1})**			
i	Ca^{++}+ Mg^{++}	8.6	Titration for Ca+Mg with standard EDTA solution as per method 7, USDA, Hand Book No. 60	Cheng and Bray (1951)
ii	Na^+	7.03	Both were measured on flame photometer as per method 10 and 11 USDA, Hand book No. 60	Cheng and Bray (1951)
iii	K^+	0.16		
2	**Anions (MeL^{-1})**			
i.	CO_3^{2-}	Nil	Titration was carried out with standard H_2SO_4 as per method, 12 USDA Hand book No. 60	Reitemier (1943)
ii	HCO_3^-	5.4		

iii	Cl^-	5.2	Titration was carried out with standard $AgNO_3$ as per method 13, USDA Hand book No. 60	Reitemier (1943)
iv	SO_4^{2-}	4.6	Modified EDTA method	Moghe *et al.* (1964)
3	pH	8.4	Using pH mete as per method of USDA Hand book No. 60	Richards (1954)
4	Ece (dsm^{-1}at 25^{0}C)	1.6	EC of water was measured with the help of "Solubridge" as per method 46, USDA Handbook No.60	Richards (1954)
5	SAR	3.39	$SAR = \frac{Na^+}{\sqrt{Ca^{2+} + Hg^{2+}/2}}$	
6	RSc (MeL^{-1}	Nil	RSC(mel^{-1})=(CO_3+ HCO_3)- (Ca+Mg)	
7	Class (USSL)*	C_3S_1		

* United State Salinity laboratory, Riverside, California, May, 1953.

Table 3.4 Treatments and their respective symbols

Treatment	**Symbols**
A. Main plot treatments	
Spacing	**4**
(ii) 30 x 10 cm	S_1
(iii) 30 x 15 cm	S_2
(iv) 45 x 10 cm	S_3
(v) 45 x 15 cm	S_4
B. Sub plot treatments	

(i)	Control	T_1
(ii)	75 % of recommended dose of NPK	T_2
(iii)	100 % of recommended dose of NPK	T_3
(iv)	125 % of recommended dose of NPK	T_4
(v)	Vermicompost @ 2.5 t ha^{-1}	T_5
(vi)	25 % of recommended dose of NPK + 2.5 t ha^{-1} vermicompost	T_6
(vii)	50 % of recommended dose of NPK + 2.5 t ha^{-1} vermicompost	T_7
(viii)	75 % of recommended dose of NPK + 2.5 t ha^{-1} vermicompost	T_8

4. EXPERIMENTAL RESULTS

Results of the field experiment entitled "Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions" conducted at S.K.N. College of Agriculture, Jobner for two consecutive *kharif* seasons, are presented and described in this chapter. Data pertaining to various criteria used for treatment evaluation were analysed statistically to test their significance and analysis of variance for these data for individual years and pooled results have been given in appendices at the end. Results for all main effects and significant interactions are presented in this chapter. In general the results are described with the help of a pooled mean.

4.1 Growth attributes

4.1.1 Plant height

The data regarding to plant height for both the years and pooled analysis are given in Table 4.1, Appendix-I, VIII and Fig. 4.1. Plant height was non-significantly affected by different plant spacings in both the years and in pooled analysis.

Though, it was significantly affected by different fertility levels during both the years and in pooled analysis. The mean maximum plant height (53.16 cm) was recorded under T_8 closely followed by T_7 while minimum (38.42 cm) was recorded in control (T_1). However, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 were at par with each other but these treatments registered 36.10, 37.84,37.48, 36.56, 37.92, 38.23 and 38.36 per cent more plant height over control (T_1), respectively.

4.1.2 Number of leaves per plant at harvest

Data pertaining to number of leaves per plant for both the years and their pooled means are presented in Table 4.2, Appendix I and VIII.

Number of leaves per plant was significantly influenced by different plant spacings during both the years and in pooled mean. The mean maximum number of leaves per plant (10.61) was observed in S_4 (45 x 15 cm) which was found to be significantly higher over S_1 (30 x 10 cm) but it was at par with S_3 (45 x 10 cm). The mean increase in number of leaves per plant under S_4 was found to be 6.10 and 6.63 per cent over S_2 and S_1, respectively.

The data presented in Table 4.2 further revealed that number of leaves per plant was also significantly influenced by various fertility levels during both the years and in pooled mean. The maximum number of leaves per plant (11.91) was observed with 50% recommended dose of NPK + vermicompost 2.5 t ha^{-1} (T_7) which was found to be significantly superior over control, T_2, T_3, T_4, T_5 and T_6. However, 50 % recommended dose of NPK + vermicompost 2.5 t ha^{-1} (T_7) was statistically at par with 75% recommended dose of NPK + vermicompost 2.5 t ha^{-1} (T_8). The mean increase in number of leaves per plant under the treatment T_7 was found to be 80.18, 21.53, 11.62, 14.96, 18.15 and 6.62 per cent over T_1, T_2, T_3, T_4, T_5 and $T_{6,}$ respectively.

4.1.3 Fresh weight of leaves at harvest

A perusal of Table 4.3, Appendix I, VIII and Fig. 4.2 revealed that fresh weight of leaves significantly affected by different levels of spacings in both the years and in pooled analysis. The maximum fresh weight of leaves was recorded in S_3 (52.69 g), which was found to be significantly higher over S_1, S_2 and $S_{4.}$

The data presented in Table 4.3 further revealed that fresh weight of leaves also influenced by different levels of fertility during both the years and in pooled means. The mean maximum fresh weight of leaves was recorded in

T_7 (56.92 g) which was found to be significantly superior over control, T_1 (32.68 g), T_2 (48.32 g), T_3 (51.19 g), T_4 (48.77g), T_5 (47.90 g) and T_6 (52.51 g). The increase in fresh weight of leaves under the treatment T_7 was found to be 74.17, 17.79, 11.19, 16.71, 18.83 and 8.39 per cent over T_1, T_2, T_3, $T_{4,}$ T_5 and T_6 respectively.

4.1.4 Dry weight of leaves at harvest (g)

The results (Table 4.4) showed that dry weight of leaves significantly affected by different levels of plant spacings in both the years and in pooled mean. The mean data for both the years clearly indicated that plant spacing S_3 produced significantly higher dry weight of leaves per plant (6.02g) followed by S_4 (5.92g) and S_2 (5.70 g) but later was at par with S_1 (5.67 g). The mean dry weight of leaves per plant with plant spacing S_3 was found to be 1.68, 5.61 and 6.17 per cent higher over S_4, S_2 and S_1, respectively.

Dry weight of leaves per plant was also significantly affected by different levels of fertility in both the years as well as in pooled analysis. The maximum dry weight (6.78g) of leaves was recorded under T_7 followed by T_8 (6.57g). While minimum was recorded under control (3.89 g). T_7 registered significantly higher dry weight of leaves on per cent basis compared to T_8 (3.19%), T_6 (8.30%), T_5 (18.73 %), T_4 (16.69 %), T_3 (11.14 %), T_2 (22.82 %) and T_1 (74.29%), respectively.

4.2 Yield and yield attributes

4.2.1 Neck thickness

A perusal of data presented in Table 4.5, Appendix-II and VIII revealed that neck thickness varied significantly with plant spacing during both the years and in pooled analysis. The minimum (0.82 cm) neck thickness of bulb was recorded with S_1 (30 x 10 cm) whereas, the maximum (0.91 cm) neck thickness of bulb was recorded with S_4 (45 x 15 cm) plant spacing.

Data (Table 4.5) further indicated that various fertility levels had significant effect on the neck thickness during both the years of study as well as in pooled analysis. The mean minimum neck thickness (0.62 cm) was observed in (T_1) control, which was found to be 44.14, 42.05, 39.21, 33.33, 23.45, 13.88 and 7.46 per cent less than T_8, T_7, T_6, T_5, T_4, T_3 and T_2 respectively. In general, from storage point of view lower neck thickness is desirable in onion.

4.2.2 Neck length

Data presented in Table 4.6, Appendix II, VIII and Fig.4.3 revealed that plant spacing had significant effect on neck length during both the years and in pooled analysis. The maximum neck length (6.31 cm) was recorded with the spacing S_4 (45 x 15 cm) non-significantly followed by S_3 (45 x 10 cm), while minimum was recorded in S_1 (5.87 cm), which was 4.94 and 7.49 per cent less compared to S_3 and S_4.

Application of different levels of fertility also had significant effect on neck length in both the years. The mean maximum neck length was recorded under T_8 (6.40 cm), T_7 (6.32 cm), T_6 (6.28 cm) and T_5 (6.21 cm); these were at par to each other. The treatment T_8, which recorded maximum neck length found to be superior over T_1, T_2, T_3 and T_4. On percentage basis, it recorded 11.69,10.15, 7.74 and 5.26 per cent, higher neck length, respectively.

4.2.3 Equatorial diameter of bulb

It is evident from Table 4.7 (a), (b), Appendix-II, IX and Fig. 4.4 that different plant spacings significantly affected the equatorial diameter of bulb during both the years and in pooled analysis. The mean maximum equatorial diameter was observed in S_4 (5.28cm) followed by S_3 (5.24 cm) but these were at par with each other. Minimum equatorial diameter was recorded in S_1 (4.92 cm). The mean increase in equatorial diameter under S_4 (45 x 15 cm) was found to be 7.31 and 1.93 per cent over S_1 and S_2, respectively.

Various fertility levels also had significant effect on equatorial diameter during both the years of study and in pooled analysis. The mean maximum equatorial diameter (5.62 cm) was recorded under 50% recommended dose of NPK + vermicompost 2.5 t ha^{-1} (T_7), while minimum (4.07) in control (T_1). The equatorial diameter recorded in treatment T_7 differed significantly from T_2, T_3, T_4, T_5 and T_6 registering 38.08, 17.08, 5.24, 7.04, 9.12 and 3.49 per cent more diameter, respectively.

Interaction effect (S x T)

Table 4.7(b) clearly indicated that combined effect of plant spacing (S) and fertility level (T) significantly affected the equatorial diameter of bulb during both the years and under pooled analysis. The pooled data indicated that treatment combination S_4T_7 produced significantly higher equatorial diameter (5.79 cm), while minimum equatorial diameter was noticed in S_1T_1 (3.52 cm).

The plant spacing S_1 (30 x 10 cm) and S_2 (30 x 15 cm) recorded the maximum equatorial diameter with 75% recommended dose of NPK along with vermicompost 2.5 t ha^{-1} (T_8), while S_3 (45 x 10 cm) and S_4 (45 x 15 cm) plant spacing recorded maximum equatorial diameter with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1} (T_7).

Table : 4.7 b Interaction effect of plant spacing x fertility level on equatorial diameter (cm).

	S_1	S_2	S_3	S_4	Mean
T_1	3.52	3.63	4.52	4.62	4.07
T_2	4.76	4.97	4.58	4.89	4.80
T_3	5.14	5.37	5.49	5.38	5.34
T_4	5.07	5.26	5.38	5.31	5.25
T_5	4.99	5.13	5.30	5.20	5.15
T_6	5.23	5.47	5.57	5.46	5.43
T_7	5.34	5.73	5.65	5.79	5.62
T_8	5.36	5.92	5.47	5.65	5.60
Mean	4.92	5.18	5.24	5.28	
		Sem$\pm$	CD 5%		
S same, T different		0.108	0.305		
S Diff., T same		0.123	0.349		

4.2.4 Polar diameter of bulb (cm)

Data pertaining to polar diameter of bulb for both the years and their pooled means are presented in Table 4.8, Appendix II, IX and Fig.4.5.

Polar diameter of bulb was significantly influenced by different plant spacings during both the years and in pooled mean. The maximum polar diameter (4.84 cm) was observed in S_3 (45 x 10 cm) which significantly differed with S_1 and S_2 but remained statistically at par with S_4 (4.81 cm). The polar diameter of bulb with plant spacing S_3 registered an increase of 4.31, 4.31 and 0.62 per cent over S_1, S_2 and S_4, respectively.

Polar diameter of bulb was also significantly affected by various fertility levels. The mean maximum polar diameter (5.25 cm) of bulb was recorded in T_7 (50 % recommended dose of NPK along with vermicompost

2.5 t ha^{-1}), while it was minimum (3.59 cm) under control. However, T_7 was at par with T_8 but differed significantly with T_1, T_2, T_3, T_4, T_5 and T_6 fertility levels. The mean increase in polar diameter under T_7 treatment was found to be 46.23, 12.90, 8.69, 10.75 , 11.94 and 5.63 per cent over T_1, T_2, T_3, T_4, T_5 and T_6, respectively.

2.4.5 Number of scales per bulb

Data (Table 4.9) showed that number of scales/bulb varied significantly. The mean data for both the years clearly indicated that plant spacing S_3 produced significantly higher number of scales per bulb (6.46) followed by S_4 (6.35), S_1 (6.23) and S_2 (6.20). The mean number of scales /bulb recorded under spacing S_3 found to be 4.19 and 3.69 per cent higher over S_1 and S_2, respectively.

Number of scales/bulb also significantly affected by various levels of fertility. The mean maximum number of scales/bulb (7.17) was recorded under T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1}), while minimum was recorded under control (4.74). Treatment T_7 differed significantly from T_1, T_2, T_3, T_4, T_5, T_6 and T_8 and registered 51.26, 22.56, 9.13, 14.53, 16.77, 5.59 and 3.16 per cent higher number of scales/ bulb , respectively.

4.2.6 Thickness of scale

Table 4.10, Appendices-III, IX and Fig.4.7 showed that different plant spacings had significant effect on the thickness of scale. The mean data for both the years indicated that plant spacing S_4 (0.244 cm) and S_2 (0.243 cm) produced thicker scales as compared to S_1 (0.231 cm) and S_3 (0.235 cm). But significant differences between S_1 and S_3 and also between S_4 and S_2 could not be recorded. The mean thickness of scale with the spacing S_4 (45 x 15 cm) registered an increase of 5.62 and 3.82 per cent over S_1 and S_3.

Application of different levels of fertility had significant influence on scale thickness (Table 4.10). The mean maximum thickness of scale (0.274 cm) was recorded under the treatment T_7, while minimum was recorded under control (0.188 cm). The scale thickness under treatment T_7 was found to be of 45.74, 29.24, 10.48, 19.65, 23.98 and 4.18 per cent over T_1, T_2, T_3, T_4, T_5 and T_6, respectively.

4.2.7 Fresh weight of bulb

It is evident from Table 4.11 (a), Appendix-III, IX and Fig 4.8 that different plant spacings significantly affected the fresh weight of bulb during both the years and under pooled analysis. The mean maximum fresh weight of bulb (80.32 g) was observed in S_4 followed by S_3 (79.09 g); these were statistically superior to S_2 and S_1. The minimum fresh weight was found in S_1 (77.41 g). The mean increase in fresh weight under S_4 (45 x 15 cm) was found to be 3.75 and 3.21 per cent over S_1 and S_2, respectively.

Various fertility levels also had significant effect on fresh weight of bulb during both the years of study and in pooled analysis. The mean maximum fresh weight of bulb (95.14 g) was recorded under 75 % recommended dose of NPK + vermicompost 2.5 t ha^{-1} (T_8) non- significantly followed by T_7 (94.78 g) while minimum (56.59 g) was in control (T_1). The fresh weight of bulb recorded in T_8 differed significantly with T_1, T_2, T_3, T_4, T_5 and T_6 and registered 68.12, 37.34, 19.62, 24.54, 33.79 and 10.01 per cent higher weight, respectively.

Interaction effect (S x T)

Table 4.11 (b) clearly indicated that combined effect of plant spacing (S) and fertility level (T) significantly affected the fresh weight of bulb during both the years and in pooled analysis. The pooled data indicated that treatment combination S_4T_8 produced significantly higher fresh weight of bulb (104.58 g), while minimum fresh weight was noticed in S_1T_1 (54.71 g).

However, under plant spacings S_1 (30 x 10 cm), S_2 (30 x 15 cm) and S_3 (45 x 10 cm) the maximum fresh weight of bulb were recorded with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1} (T_7), while in S_4 (45 x 15 cm) plant spacing the maximum fresh weight of bulb was recorded with 75 % recommended dose of NPK + vermicompost 2.5 t ha^{-1} (T_8).

Table : 4.11b Interaction effect of plant spacing x fertility levels on fresh weight of bulb (g)

	S_1	S_2	S_3	S_4	Mean
T_1	54.99	55.74	56.55	59.10	56.59
T_2	68.14	68.92	68.92	71.07	69.27
T_3	77.95	78.20	80.16	81.83	79.53
T_4	74.95	75.19	76.65	78.78	76.39
T_5	69.95	70.19	70.99	73.30	71.11
T_6	85.01	85.33	86.78	88.81	86.48
T_7	96.95	97.17	99.91	85.10	94.78
T_8	91.38	91.80	92.78	104.58	95.14
Mean	77.41	77.82	79.09	80.32	
		SEm±	CD 5%		
S same, T different		0.877	2.459		
S different, T same level		1.0847	3.1032		

4.2.8 Volume of bulb

The results (Table 4.12) showed that volume of bulb was significantly affected by different plant spacings. The mean data for both the years clearly indicated that plant spacing S_4 had maximum volume of bulb (53.09 cc) followed by S_3 (52.98 cc) but these were statistically at par with each other. Volume recorded under plant spacing S_3 was 6.70 and 3.67 per cent higher than S_1 and $S_{2,}$ respectively. S_1 and S_2 were statistically at par to each other.

Volume of bulb was also significantly affected by different fertility levels. The mean maximum volume of bulb (56.03 cc) was recorded in T_7 (50 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}), while it was minimum (41.63 cc) in control. However, T_7 was at par with T_8 but differed significantly with T_1, T_2, T_3, T_4, T_5 and T_6. The mean increase in volume of bulb under the treatment T_7 was found to be 34.59, 16.60, 4.26, 4.72, 9.47 and 3.05 per cent over T_1, T_2, T_3, T_4, T_5 and T_6, respectively.

4.2.9 Bulb yield

The data reported in Table 4.13 a, b, Appendix-IV, X and Fig.4.10 revealed that different plant spacings and fertility levels and their interaction effect significantly influenced the bulb yield per hectare in both the years and in pooled analysis. The mean maximum bulb yield (257.96 q ha^{-1}) was observed in S_1 (30 x 15 cm), which significantly differed with S_4 (115.65 q ha^{-1}), S_3 (174.64 q ha^{-1}) and S_2 (172.97 q ha^{-1}). S_3 and S_2 were statistically at par to each other. Plant spacing S_1 recorded an increase in bulb yield of 49.13, 47.70 and 123.05 per cent over S_2, S_3 and S_4, respectively.

Bulb yield was also significantly affected by different fertility levels during both the years and in pooled analysis. The mean maximum bulb yield (224.29 q ha^{-1}) was recorded in T_7 while it was minimum (128.76 q ha^{-1}) in control. Treatment T_7 was found significantly superior over T_1, T_2, T_3, T_4, T_5, T_6 and T_8 and registered an increase in bulb yield of 74.19, 41.49, 23.21, 28.18, 39.07, 13.22 and 4.54 per cent, respectively.

Interaction effect (S x T)

Table 4.13(b) clearly showed that combined effect of plant spacing (S) and fertility level (T) significantly affected the bulb yield during individual years and in pooled analysis. The pooled mean indicated that treatment combination S_1T_7 produced significantly higher bulb yield (323.96 q ha^{-1}), while minimum bulb yield was observed in S_4T_1 (82.62 q ha^{-1}).

However, under plant spacings S_1 (30 x 10 cm), S_2 (30 x 15 cm) and S_3 (45 x 10 cm), the maximum bulb yield were recorded with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1}, while in S_4 (45 x 15 cm) plant spacing, the maximum bulb yield was recorded with T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1}).

Table : 4.13 b Interaction effect of plant spacing x fertility level on bulb yield (q/ha) of onion.

	S_1	S_2	S_3	S_4	Mean
T_1	184.03	123.85	124.55	82.62	128.76
T_2	227.91	153.18	152.04	100.91	158.51
T_3	260.53	173.76	177.02	116.82	182.03
T_4	250.46	168.07	169.22	112.12	174.97
T_5	228.88	155.62	156.64	103.93	161.27
T_6	284.20	189.40	191.73	127.10	198.10
T_7	323.96	215.93	220.91	136.39	224.29
T_8	303.75	204.00	205.06	145.36	214.54
Mean	257.96	172.97	174.64	115.65	
		Sem±	CD 5%		
S same, T different		5.209	14.601		
S Diff., T same		6.331	18.089		

4.3 Quality attributes

4.3.1 Total soluble solids (TSS)

A perusal of data (Table 4.14) revealed that different plant spacings had non-significant effect on TSS during both the years of experimentation as well as in pooled analysis.

Whereas, application of different fertility levels to onion had significant effect on TSS under pooled analysis. The mean maximum TSS (12.36 %) was recorded under T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1}) closely followed by T_7 (50 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}) while minimum TSS (12.04%) was in control. The treatments T_3, T_4, T_5, T_6, T_7 and T_8 were statistically at par to each other.

4.3.2 Sulphur content in bulb

The data reported in Table 4.15, Appendix-V, X and Fig.4.12 explicit that sulphur content in bulb was non- significantly affected due to different plant spacings.

However, sulphur content was significantly affected by different fertility levels in both the years and in pooled analysis. The mean maximum sulphur content (0.692 %) of bulb was recorded in $T_{7,}$ while minimum (0.637 %) was in control (T_1). Though fertility level T_7 was at par with T_6 and T_8 but differed significantly with T_1, T_2, T_3, T_4 and T_5. The fertility level T_7 recorded 8.63, 5.16, 2.06, 2.97 and 3.90 per cent more sulphur content in bulb over T_1, T_2, T_3, T_4 and T_5, respectively.

4.3.3 Pungency (Allyl propyl disulphide)

The results (Table 4.16) showed that allyl- propyl-disulphide was non-significantly affected by different plant spacings.

Different fertility levels influenced pungency significantly. Maximum (7.23 mg/100 g) pungency was recorded in T_7 (50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1}) fertility level, which was found to be significantly superior over T_1 (6.57 mg/ 100g), T_2 (6.67 mg/100 g), T_3 (6.95 mg/100 g), T_4 (6.81 mg/100 g), T_5 (6.74 mg/100g) and T_6 (7.01 mg/100g). Thereby T_7 recorded 10.04, 8.39, 4.02, 6.16, 7.27 and 3.13 per cent more allyl propyl disulphide over T_1, T_2, T_3, T_4, T_5 and T_6, respectively. T_7 and T_8 were at par.

4.3.4 Vitamin 'C' content (Ascorbic acid)

A perusal of Table 4.17, Appendix IV, X and Fig. 4.13 revealed that vitamin 'C' varied non- significantly due to different plant spacings.

Ascorbic acid content was significantly affected by different fertility levels in individual year and in pooled analysis. The mean maximum vitamin 'C' content (9.68 mg/100 g) of bulb was recorded in T_8 (75 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}) while, minimum (9.20 mg/100g) was in control. Fertility levels T_1 and T_2 were statistically at par with each other but significantly differed with T_3, T_4, T_5, T_6, T_7 and T_8. The fertility level T_8 recorded 5.21, 4.87, 2.54 and 3.41 per cent more ascorbic acid content as compared to T_1, T_2, T_4 and T_5, respectively.

4.3.5 Nitrogen content in bulb

The data reported in Table 4.18, Appendix-V, XI and Fig.4.15 explicit that nitrogen content in bulb was significantly affected by various plant spacings during both the years and in pooled analysis. The mean maximum nitrogen content in bulb (0.786 %) was recorded in S_3 (45 x 10 cm), while minimum was in S_1 (30 x 10 cm). Plant spacing S_3 produced 3.42 and 2.34 per cent higher nitrogen content over S_1 and S_2, respectively.

Application of different fertility levels also had significant effect on nitrogen content in bulb. Maximum (0.853 %) nitrogen content in bulb was recorded in T_8 (75 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1}) while minimum was in T_1 (0.539 %).

4.3.6 Phosphorus content in bulb

A perusal of Table 4.19, Appendix-V, XI and Fig.4.16 revealed that phosphorus content in bulb was significantly affected by different plant spacings. The mean maximum phosphorus content in bulb (0.357 %) was recorded with S_3 (45 x 10 cm) plant spacing while minimum (0.339 %) was with S_1 (30 x 10 cm). S_3 recorded 5.30 per cent more phosphorus content in bulb over S_1.

Different fertility levels also had significant effect on phosphorus content in bulb during both the years and in pooled analysis. The mean maximum phosphorus content (0.474 %) was recorded under T_7 (50 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}) followed by T_8 (75 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}) while minimum (0.263 %) in control. The phosphorus content in bulb recorded under the treatment T_7 registered an increase of 80.22, 69.28, 38.19, 50.47, 60.67, 24.73 and 10.23 per cent over T_1, T_2, T_3, T_4, T_5, T_6, and T_8 respectively.

Interaction (S x T)

Further, Table 4.19(b) clearly indicated that combined effect of plant spacing(s) and fertility level (T) significantly affected the phosphorus content. The pooled data indicated that treatment combination S_2T_7 gave significantly higher phosphorus content in bulb (0.485 %), while minimum phosphorus content was noticed in S_1T_1 (0.255 %).

However, under plant spacings S_1 (30 x 10 cm), S_2 (30 x 15 cm), S_3 (45 x 10 cm) and S_4 (45 x 15 cm), the maximum phosphorus content in bulb were recorded with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1} (T_1).

Table : 4.19b Interaction effect of plant spacing x fertility levels on phosphorus content (%) in onion

	S_1	S_2	S_3	S_4	Mean
T_1	0.255	0.260	0.265	0.270	0.263
T_2	0.285	0.270	0.285	0.280	0.280
T_3	0.330	0.335	0.350	0.355	0.343
T_4	0.310	0.320	0.315	0.315	0.315
T_5	0.295	0.285	0.305	0.294	0.295
T_6	0.405	0.415	0.460	0.440	0.430
T_7	0.465	0.485	0.480	0.465	0.474

T_8	0.365	0.375	0.395	0.385	0.380
Mean	0.338	0.343	0.357	0.351	
		SEm±	CD 5%		
S same, T different		0.00639	0.0179		
S different, T same level					

4.3.7 Potassium content in bulb

The Table 4.20, Appendices VI, XI and Fig.4.17 showed that different plant spacings had significant effect on the potassium content in bulb during both the years and in pooled analysis. The mean maximum potassium content in bulb (1.12 %) was recorded in S_3 and S_4 plant spacings. Whereas, minimum potassium content in bulb was recorded with S_1 and S_2 plant spacings. The mean increase in potassium content under S_3 and S_4 was found to be 2.75 per cent over S_1 and S_2, respectively.

Fertility levels to onion also had significant effect on potassium content. The mean maximum potassium content in bulb (1.12 %) was recorded under T_3, T_6, T_7 and T_8 while minimum (1.08 %) was recorded in control (T_1).

4.4 NPK Uptake

4.4.1 Nitrogen uptake in bulb

The results (Table 4.21) showed that uptake of nitrogen was significantly affected by different plant spacings. The mean maximum nitrogen uptake in bulb (199.30 kg ha^{-1}) was recorded under S_1 (30 x 10 cm) while minimum (91.45 kg ha^{-1}) was in S_4 (45 x 15 cm). Nitrogen uptake in S_1 registered an increase of 47.54, 42.51 and 117.93 per cent over S_2, S_3 and S_4, respectively.

Application of different fertility levels also had significant effect on nitrogen uptake. The mean maximum nitrogen uptake (182.42 kg ha^{-1}) was recorded under T_8 (75 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}) whilest, minimum (69.20 kg ha^{-1}) was recorded in control (T_1).

The fertility level T_8 recorded 163.61, 52.81, 25.23, 31.50, 44.38, 13.31 and 8.17 per cent higher uptake over T_1, T_2, T_3, T_4, T_5, T_6 and T_7, respectively.

Interaction (S x T)

Combined effect of plant spacing and fertility level significantly influenced the nitrogen uptake in bulb (Table 4.21b). Pooled mean indicated that the treatment combination S_1T_7 resulted in significantly higher (264.35 kg ha^{-1}) while minimum (44.72 kg ha^{-1}) uptake was recorded in S_4T_1.

However, under plant spacings S_1 (30 x 10 cm), S_2 (30 x 15 cm) and S_3 (45 x 10 cm), the maximum nitrogen uptake in bulb were recorded with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1}. While in S_4 (45 x 15 cm) plant spacings the maximum nitrogen uptake was recorded with 75% recommended dose of NPK along with vermicompost 2.5 t ha^{-1}.

Table : 4.21b Interaction effect of plant spacing x fertility levels on nitrogen uptake (kg ha^{-1}) in onion

	S_1	S_2	S_3	S_4	Mean
T_1	98.00	66.38	67.69	44.72	69.20
T_2	170.49	114.80	115.83	76.35	119.37
T_3	206.08	139.27	143.64	93.66	145.66
T_4	196.49	133.48	136.24	88.66	138.72
T_5	176.96	121.67	124.48	82.24	126.34
T_6	228.07	154.26	156.19	103.43	160.99
T_7	264.35	177.82	194.49	117.87	188.63

T_8	253.93	172.90	178.21	124.64	182.42
Mean	199.30	135.08	139.85	91.45	
		SEm$\pm$	CD 5%		
S same, T different		4.339	12.163		
S different, T same level		5.573	15.989		

4.4.2 Phosphorus uptake in bulb

Data (Table 4.22 and Appendix-VI, XI) clearly indicated that different plant spacings significantly affected the phosphorus uptake in bulb during both the years and in pooled analysis. The mean maximum phosphorus uptake in bulb (89.96 kg ha-^{1}) was recorded under S_1 (30 x 10 cm), whereas minimum (41.67 kg ha^{-1}) was in S_4 (45 x 15 cm) . Thus, the mean phosphorus uptake in S_1 registered an increase of 46.92, 39.84 and 115.88 per cent over S_2, S_3 and S_4, respectively.

Application of different fertility levels also had significant effect on phosphorus uptake. The maximum mean phosphorus uptake (106.23 kg ha^{-1}) was recorded in T_7 while, minimum (33.59 kg ha^{-1}) was in control (T_1).

The fertility level T_7 (50 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}) recorded 216.25, 138.45, 71.53, 93.07, 123.35, 25.87 and 31.00 per cent more uptake of phosphorus over T_1, T_2, T_3, T_4, $T_{5,}$ T_6 and T_8, respectively.

Interaction (S x T)

Combined effect of plant spacing and fertility level significantly influenced the phosphorus uptake in bulb (Table 4.22b). Pooled mean indicated that the treatment combination S_1T_7 resulted in significantly higher

(150.64 kg ha^{-1}) phosphorus uptake in bulb. While minimum (22.31 kg ha^{-1}) phosphorus uptake in bulb was recorded under the treatment combination S_4T_1.

However, under spacings S_1 (30 x 10 cm), S_2 (30 x 15 cm), S_3 (45 x 10 cm) and S_4 (45 x 15 cm) the treatment T_7 recorded the maximum phosphorus uptake in bulb.

Table : 4.22b Interaction effect of plant spacing x fertility levels on phosphorus uptake (kg ha^{-1})in onion

	S_1	S_2	S_3	S_4	Mean
T_1	46.93	52.20	32.94	22.31	33.59
T_2	64.97	41.35	43.46	28.43	44.55
T_3	85.98	58.22	61.97	41.56	61.93
T_4	77.65	53.83	53.16	35.56	55.02
T_5	67.56	44.42	47.80	30.45	47.56
T_6	115.10	78.52	88.18	55.74	84.39
T_7	150.64	104.73	106.09	63.45	106.23
T_8	110.87	76.52	81.09	55.96	81.09
Mean	89.96	61.23	64.33	41.67	

	SEm±	CD 5%
S same, T different	2.133	5.960
S different, T same level	2.813	8.085

4.4.2 Potassium uptake in bulb

A perusal of pooled data (Table 4.23) revealed that plant spacing varied significantly with regard to potassium uptake. The mean maximum potassium uptake (280.78 kg ha^{-1}) was recorded in S_1 (30 x 10 cm). Whereas, minimum was recorded in S_4 (129.34 kg ha^{-1}). However, plant spacings S_2 (30 x 15 cm) and S_3 (45 x 10 cm) were statistically at par with each other. The plant spacing S_1 recorded 47.92, 42.54 and 117.08 per cent more potassium uptake over S_2, S_3 and S_4, respectively.

Data (Table 4.23) further revealed that fertility levels increased potassium uptake significantly during both the years of study and in pooled analysis. The mean maximum potassium uptake (252.05 kg ha^{-1}) was observed in T_7 Whereas, minimum (139.14 kg ha^{-1}) was in control (T_1). The potassium uptake of bulb recorded under T_7 registered an increase of 81.14, 46.36, 24.52, 31.34, 43.04 14.27 and 5.31 per cent K uptake over T_1, T_2, T_3, T_4, T_5, T_6 and T_8, respectively.

4.5 Available NPK in soil after harvesting

4.5.1 Available N in soil after harvesting

Table 4.24 indicated that average available nitrogen in soil after harvesting of onion crop was significantly affected by different plant spacings during both the years and in pooled analysis. The mean maximum average nitrogen content in soil (138.74 kg ha^{-1}) was recorded under S_3 (45 x 10 cm) plant spacing followed by S_4 (45 x 15 cm), while minimum was under S_1 (127.16 kg ha^{-1}). Data further indicated that S_3 plant spacing recorded 9.10 and 8.48 per cent more nitrogen content in soil after harvesting over S_1 and S_2 , respectively.

The perusal of data in Table 4.24 and Appendix-VII, XII revealed that increasing levels of fertility increased the average available nitrogen content in soil significantly. The mean maximum available nitrogen content (140.76 kg ha^{-1}) was recorded in T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1}), while minimum (102.74 kg ha^{-1}) was recorded in T_1. However, treatment T_7 was statistically at par with T_6 and T_8. The fertility level T_7 recorded 37.00, 11.36, 3.79 and 5.58 per cent more available nitrogen over T_1, T_2, T_3 and T_5, respectively.

4.5.2 Available P_2O_5 in soil after harvesting

Table 4.25 indicated that average available P_2O_5 content in soil after harvesting was affected significantly by different plant spacings during both the years and in pooled analysis. The mean maximum P_2O_5 (16.79 kg ha^{-1}) in soil after harvesting was recorded under S_4 (45 x 15 cm) followed by S_3 and S_2 whereas, minimum (15.93 kg ha^{-1}) was recorded under S_1 (30 x 10 cm). The available P_2O_5 in soil after harvesting with S_4 spacing recorded an increase of 5.39 and 0.90 per cent over S_1 and S_2, respectively.

The perusal of Table in 4.25 and Appendix VII, XII further revealed that fertility levels also had significant influence on available P_2O_5 in soil after harvesting during individual year and in pooled analysis. The mean maximum (18.39 kg ha^{-1}) available P_2O_5 in soil after harvesting was recorded in T_7 whereas, minimum (14.26 kg ha^{-1}) was in control (T_1). The available P_2O_5 recorded in T_7 fertility level registered an increase of 28.96, 19.88, 8.68, 12.33, 15.29 and 8.43 per cent over T_1, T_2, T_3, T_4, T_5 and T_6, respectively. T_7 and T_8 treatments were statistically at par with each other.

4.5.3 Available K_2O in soil after harvesting

The data presented in Table 4.26 and Appendix-VII and XII explicit that available K_2O in soil after harvesting was significantly affected by different plant spacings. The mean maximum available K_2O in soil after harvesting (138.60 kg ha^{-1}) was recorded under S_4 plant spacing (45 x 15 cm), while minimum (129.61 kg ha^{-1}) was recorded under S_1 (30 x 10 cm). S_1 and S_2 were statistically at par with each other.

Similarly, available K_2O in soil after harvesting was also significantly affected by different fertility levels. The mean maximum available K_2O in soil after harvesting (141.32 kg ha^{-1}) was recorded under T_7 , while minimum (110.78 kg ha^{-1}) under control (T_1). However, fertility levels T_6, T_7, $T_{4,}$ T_3 and T_8 were statistically at par with each other. T_7 recorded 27.56, 7.75, 3.33 and 4.46 per cent more K_2O content in soil over T_1, T_2, T_4 and T_5, respectively.

4.6 Correlation coefficient

Correlation coefficients among various growth, yield and quality parameters and nutrient content and uptake with bulb yield have been presented in Table 4.27

Bulb yield per plant had significant and positive correlation with N uptake (0.970), P uptake (0.904), fresh weight of bulb (0.509), number of scales/bulb (0.419), P content (0.395), K uptake (0.393), vitamin ‘C’ content (0.373), N content (0.358) and pungency (0.354). Other characters showed positive though non-significant correlation with bulb yield. Fresh weight of leaves exhibited significant positive correlation with N content (0.957), volume of bulb (0.926), number of scales (0.886), equatorial diameter (0.874) S content (0.874), thickness of scale (0.749), fresh weight of bulb (0.734), TSS (0.733), pungency (0.717), vitamin ‘C’ (0.688), K content (0.657), neck thickness (0.648), P content (0.599) and N uptake (0.357). Volume of bulb showed significant positive correlation with S content (0.968), number of scales (0.951), equatorial diameter (0.938), N content (0.936), thickness of scale (0.888), vitamin ‘C’ (0.882), pungency (0.871), TSS (0.862), fresh weight bulb (0.857), neck thickness (0.769), K content (0.765), P content (0.754), P uptake (0.453), and N uptake (0.422). Fresh weight of bulb had significant positive correlation with thickness of scale (0.939), no. of scales (0.932), pungency (0.929), S content (0.926), vitamin “C” (0.920), TSS (0.887), P content (0.874), N content (0.840), neck thickness (0.827), equatorial diameter (0.823), P uptake (0.751), N uptake (0.674), K content (0.633) and K uptake (0.551). Number of scales exhibited significant positive correlation with S content (0.978), N content (0.947), thickness of scale (0.931), pungency (0.923), vitamin ‘C’ (0.907), equatorial diameter (0.890), TSS (0.877), P content (0.838), neck thickness (0.807), K content (0.700), P uptake (0.648), N uptake (0.613) and K uptake (0.463). Neck thickness showed significant correlation with TSS (0.973), thickness of bulb (0.833), S content (0.826) pungency (0.808), P content (0.795), vitamin “C" (0.794), N content (0.726), equatorial diameter (0.706), K content (0.601), P uptake (0.535), and N uptake (0.435). Equatorial bulb diameter revealed significantly positive correlation with S content (0.921), N content (0.893), thickness of bulb (0.868), vitamin ‘C’ (0.845), TSS (0.843), pungency (0.821), P content (0.715), K content (0.680), P uptake (0.443) and N uptake (0.424). Thickness of scale showed significantly positive correlation with S content (0.948), vitamin “C” (0.947), pungency (0.942), P content (0.891), TSS (0.886), N content (0.834), K content (0.682) , N uptake (0.530) and K uptake (0.389). TSS showed significant correlation with S content (0.895), pungency (0.861), vitamin ‘C’ (0.857), N content (0.813) P content (0.799), K content (0.640), P uptake (0.779), K content (0.771), P uptake (0.638), N uptake (0.544) and K uptake (0.422). Pungency showed significant and positive correlation with S content (0.943), P content (0.940), N content (0.778), K content (0.778), P uptake (0.664) and N uptake (0.523).

The correlation among the growth and yield parameters inter se revealed that all the character combinations had significant positive correlation.

Correlation coefficient among the quality parameters revealed positive and significant inter relationship among various quality parameters. N content showed significant and positive correlation with S content (0.918), P content

(0.659), K content (0.585), N uptake (0.564), P uptake (0.513) and K uptake (0.393). P content revealed significantly positive correlation with S content (0.857), P uptake (0.729), K content (0.676), N uptake (0.529) and K uptake (0.440). S content exhibited significant and positive correlation with P uptake (0.583), N uptake (0.522), and K uptake (0.365). N uptake had significant and positive correlation with K uptake (0.979) and P uptake (0.936).

Correlation coefficient among the nutrient content and nutrient uptake characters revealed that K content had positive but non-significant correlation with N uptake, P uptake and K uptake.

N uptake had positive and significant correlation with all the growth, yield and quality parameters.

4.7 Economics

Data presented in appendix-XIII indicated that general cost of *kharif* onion cultivation was Rs 20,600.00 per hectare including labour cost , cost of various material in puts and over head costs.

Treatment wise additional cost including cost of NPK fertilizer, vermicompost, seed labour charges for sowing, hoeing and weeding, are given in appendix-XIII.

The economics of various treatment combinations with benefit: cost ratio are given in table 4.29. Before selling, the onion bulbs were graded into three grades *viz.*, ‘A’, ‘B’ and ‘C’. These ‘A’, ‘B’ and ‘C’ grade bulbs were sold at the price of Rs.850, 700 and 550 per quintal, respectively. The net profit from cultivation under different treatments were worked out after substracting the cost of cultivation from gross returns.

The data revealed that the maximum net profit of Rs 155721.00 ha^{-1} was obtained under the treatment combination S_3T_7 (45 cm row to row and 10 cm plant to plant distance +50 % recommended dose of NPK along with vermicompost 2.5 tha^{-1}). Which was closely followed by S_1T_7(30 cm row to row and 10 cm plant to plant distance + 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1}) with a profit of Rs.145625.00 ha^{-1}. The minimum net profit of Rs 42218.00 ha^{-1} was gained under the treatment combination S_4T_1 (45 cm row to row and 15 cm plant to plant distance + no fertilizer application).

Data presented in same table further revealed that S_3T_7 treatment combination resulted in the highest B:C ratio of 4.85:1 which was closely following by S_1T_7 (30 x 10 cm + 50 % recommended dose of NPK alongwith 2.5 % vermicompost ha^{-1}) whereas, the minimum benefit cost ratio (1.28:1) was obtained under the treatment combination S_4T_1 .

Therefore, it could be inferred from the above findings that S_3T_7 was the most economical combination because it gave highest benefit ratio (4.85:1).

Appendix-XIII

A. General cost of onion cultivation (Rs ha^{-1})

(Excluding the cost of the treatment inputs)

	Particulars	Unit	Cost/unit (Rs.)	Cost/ha (Rs.)
I.	Variable cost			
A.	Labour charge			
(a)	Layout of experiment field	5 manday	60.00 manday^{-1}	300
(b)	Preparation nursery seed bed and preparation of the onion bulb	12 manday	60.00 manday^{-1}	720
(c)	Sowing of seed and seed bed	5 manday	60.00 manday^{-1}	300
(d)	Weeding and care of	8 manday	60.00 manday^{-1}	480

	nursery beds			
(e)	Gap filling	4 manday	60.00 manday^{-1}	240
(f)	Irrigation of labour	40 manday	60.00 manday^{-1}	2400
(g)	Spraying of fungicides and insecticides	8 man day	60.00 manday^{-1}	480
(h)	Harvesting of bulb	35 manday	60.00 manday^{-1}	2100
(i)	Miscellaneous expenses	-	-	140
				7160
B.	Service charges for land preparation by tractor	10 hours	1300/ hr.	1300
C.	Material inputs			
(a)	Seed charge	10 kg	120/ kg	1200
(b)	Vermicompost	12500 kg	2/ kg	5000
(c)	Electricity and other costs (irrigation)	5 irrigation	120/ irrigation	600
(d)	Mancozeb	1 lit.	900/ lit.	900
(e)	Karanthen	1.5 lit.	100/ lit.	1500
(f)	Malathion 50 EC	1.5 lit.	160/ lit.	240
(g)	Application of FYM	20 tones	80/ lit.	1600
				11040
II.	Over head costs			
(a)	Rental value of land			1200.00
(b)	Interest on working capital			800.00
(c)	Depreciation cost			400.00
				2400.00

General cost of cultivation = (A) + (B) + (C) + II

= 7160 + 11040 + 2400 = 20, 600

B. Variable cost due to treatments

	S_1 (30 x 10 cm) (12 kg)	S_2 (30 x 15 cm) (11 kg)	S_3 (45 x 10 cm) (11 kg)	S_4 (45 x 15 cm) (9 kg)
Seed	1320	1200	1200	1080
Hoeing and weeding	1480	1340	1340	1275
Transplanting	3000	2800	2800	2400
	5800	5300	5300	4755

A cost variation due to fertilizer application

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Vermicompost	0.00	0.00	0.00	0.00	5000	0.00	0.00	0.00
Nitrogen	0.00	652	869	1086.95	-	163	434.76	652

Phosphorus	0.00	703	937	1171.87	-	254	468.75	703
Potassium	0.00	375	499	624.99	-	125	250	375
	0.00	1730	2305	2883	5000	5542	6153.53	6730

5. DISCUSSION

In the course of presenting the results (Chapter IV) of experiment entitled "Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion under semi arid condition", significant variation in the criteria used for evaluating the treatments have been described. In the present chapter it is endeavoured to discuss the significant results or those assuming a definite pattern in various parameters in the light of available evidences in literature.

5.1. Growth attributes

5.1.1 Effect of plant geometry

Plant spacing had non-significant effect on plant height (Table 4.1). Similar results were also reported by Verma *et al.* (1972) in onion. Significantly higher number of leaves and more fresh and dry weight of leaves at harvest were noticed with the wider plant spacing i.e. 45 X 10 cm and 45 X 15 cm. This might be due to the fact that wider plant spacing caused lesser competition for space, nutrients and light. The increase in growth due to wider spacing have also been reported by Singh *et al.* (1955) and Naruka (2000) in garlic; Khushi *et al.* (1990), Kumar *et al.* (1998) and Naik and Hosamani (2000) in onion.

5.1.2. Effect of fertility levels

Significantly more plant height, number of leaves per plant, fresh and dry weight of leaves per plant at harvest were recorded with 50 per cent recommended dose of NPK along with vermicompost 2.5 t ha^{-1} (Table 4.1, 4.2, 4.3 and 4.4). However, this treatment was statistically at par with 75 per cent recommended dose of NPK alongwith vermicompost 2.5 t ha^{-1}. This may be attributed to better nutritional environment in the root zone as well as in the plant system. It is well established that nitrogen is the most indispensable of all mineral nutrients for growth and development of the plant as it is the basis of fundamental constituents of all living matter. It also plays an important role in plant metabolism by virtue of being an essential constituent of diverse types of metabolically active compounds like amino acids, proteins, nucleic acids, prophyrins, flavins, purine and pyrimidine, nucleotides, flavin nucleotides, enzymes, co-enzymes and alkaloid (Yadav, 2000).

The response to potassium fertilization in terms of overall improvement in growth parameters is further supported by the fact that the leaching losses of potassium was more in light textured soils. Therefore, potassium fertilization improved overall crop growth in terms of plant height, number of leaves plant^{-1}, fresh and dry weight of leaves. The findings of this investigation were in close conformity with those of Singh *et al.* (1989), Baloch *et al.* (1991), Vachhani and Patel (1993) and Rizk (1997) in onion . Integrated nutrient management approach for the crops by judicious mixture of organic manures along with inorganic fertilizers has a number of agronomical land environmental efficiencies. Integrated system approach is not only a liable way for obtaining fairly high productivity with substantial fertilizer economy but also a concept of ecological soundness leading to sustainable agriculture (Swaminathan, 1987). The improvement in plant height, number of leaves with the application of FYM and vermicompost might be due to better moisture holding capacity and supply and availability of major and micro nutrients due to favourable soil condition (Reddy *et al.*, 1998). In case of vermicompost, the earthworm carts help in improving the soil fertility and availability of nutrients besides some growth stimulating substances excreted by earthworm into their carts. (Senapati *et al.*, 1985). The present trend of increase in growth parameters is in close conformity with the findings of Reddy *et al.* (1998) in pea and Sharhidhara *et al.* (1998) in chilli. The better growth of plant in terms of dry matter accumulation could also be attributed due to enhanced release of nutrients from the added source of N, P and K as well as release of nutrients on mineralisation and changes in the physico-chemical properties of soil due to application of organic carbon in the form of vermicompost thereby improvement in soil nutrients status . The interactive influence of mineral nutrients and FYM on growth might be due to improved physical, chemical and biological properties like water holding capacity, hydraulic conductivity, high rate of microbial transformations due to availability of organic carbon in the form of FYM for heterotrophic organisms, buffering effect, improved soil aggregation, aeration, release of organic acid, etc. Which might act as stimulant for supply of crop nutrients during the course of decomposition. Results of Patel *et al.* (1986), Singh and Mishra (1986) and Rabindra *et al.* (1988) also revealed that there was higher release of nutrients from added sources ; it was otherwise not available.

5.2. Yield attributes and yield

5.2.1 Effect of plant geometry

Results showed that neck thickness, neck length, equatorial diameter, polar diameter, number of scales bulb^{-1}, thickness of scales, fresh weight of bulb, volume of bulb and yield hectare^{-1} increased with the wider plant spacing 45 X 15 cm or 45 X 10 cm (Table 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11 and 4.12). This might be due to lesser number of plants in a given area causing lesser competition for nutrient and light, increasing food assimilatory efficiency and thereby deposited more food in bulbs. Due to these reasons neck thickness, neck length, equatorial diameter, polar diameter, number of scales bulb^{-1}, thickness of scales, fresh weight of bulb and volume of bulb probably increased. However, maximum bulb yield was recorded in closer plant spacing (30 X 10 cm), whereas minimum in wider plant spacing (45 X 15 cm). This was probably due to lesser number of bulbs accommodated in wider spacing. Increased yield of onion due to closer spacing had also been reported by Das *et al*. (1972), Singh *et al*. (1972), Randhawa and Singh (1974), Rashid and Rashid (1976), Mangual *et al.* (1979), Khushi *et al.* (1990), Singh (1995), Kumar *et al*.(1998) Naik and Hosmani (2000), Yadav *et al.* (2002) in onion; Sharma and Koul (2002) in leek.

5.2.2. Effect of fertility levels

In general, the significant improvement in yield attributing traits of onion with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1} (Table 4.1, 4.2, 4.3 and 4.4) could be ascribed to overall improvement in vigour and crop growth as already been explained in preceding paragraphs. Since an adequate supply of nitrogen in the life of a plant is considered to be important in promoting rapid vegetative growth, including plant height, number of leaves plant^{-1} and fresh and dry weight of leaves, thereby increasing the sink size in terms of bulb size. Thus, nitrogen fertilization stimulated neck thickness, neck length, bulb diameter (equatorial and polar), number of bulbs and volume of bulb significantly (Table 4.5 to 4.13).

Improved overall growth i.e. plant height, number of leaves plant^{-1} and fresh weight of leaves with the nitrogen fertilization coupled with increased net photosynthesis on one hand and greater mobilization of photosynthates towards depository structure, on the other hand might have increased the yield significantly. Nitrogen application further helps in the translocation of photosynthates in storage organ of bulb resulting in increased diameter and weight of bulb. On the contrary, deficiency of nitrogen in the experimental field as observed from table 3.3 affected the crop growth, bulb diameter, scale thickness, number of scales bulb^{-1}, fresh weight of bulb and volume of bulb adversely under control. The bulb yield, being a function primarily of the cumulative effect of these parameters, increased significantly upto 224.29 q ha^{-1} with 50 per cent recommended dose of NPK along with vermicompost 2.5 t ha^{-1}. There was a real improvement in bulb yield with the nitrogen fertilization which can be further evidenced by the fact that there was positive and significant correlation between bulb yield and yield attributes (Table 4.28). Improved fresh weight of bulb and fresh weight of leaves as explained earlier with nitrogen fertilization led to significant improvement in biological yield and resulted in better source and sink relationship.

The beneficial influence of phosphorus in early stages of growth may be explained by early stimulation of scanty root system through efficient translocation to the roots of certain growth stimulating compounds formed on account of photoplasmic activity of tops in phosphorus fed plants, which enhanced absorption of nitrogen and other nutrients and their utilization.

Since an adequate supply of potassium stimulated neck thickness, neck length, bulb diameter (polar & equatorial), number of scales bulb^{-1}, scale thickness, fresh weight of bulb, volume of bulb and yield (Table 4.5 to 4.13). The increase in yield attributes and yield due to potassium application may be due to its functional role as potassium resulting higher net photosynthetic activity. Adequate nutrient supply caused denser rooting system, which results into improvement in yield attributing characters and yield (Sharma *et al.*, 1994).

The importance of earthworm carts in improving the soil fertility and increasing growth and yield of crops have been advocated by many workers (Najawan and Kanwar,1952; Satchell 1958; Kale and Bano,1986; Bawalker, 1992; Tomati *et al.* 1988). Vermicompost also contains higher level of nutrients besides some growth stimulating substance excreted by earthworm into their carts. It has also been reported that vermicompost is an important biofertilizer that can be used in vegetables like turmeric which contains 2-10 times more utilizable nutrients than soil (Vadiraj *et al.,* 2001).

In the study when vermicompost was used @ 2.5 t ha-^{1} along with 50 per cent recommended dose of NPK, the yield was increased by 74.19 per cent over control and by 39.07 per cent over the treatment, vermicompost alone. Besides the above facts the vermicompost having a material which has high porosity, aeration, drainability and water holding capacity. It contains nutrient in readily available form to the plants such as nitrate, exchangeable phosphorus soluble potassium, calcium and magnesium. It also contains biologically active substances such as plant growth regulators (Krishnamoorthy and Vajranabhaiah, 1986; Graphalli *et al.*, 1987).

The present trends of increase in bulb yield and yield attributes with 50 per cent recommended dose of NPK along with vermicpompost 2.5 t ha^{-1} is in close conformity with the findings of Mahendran and Kumar (1997) in cabbage, Sreenivas *et al*.(2000) in ridge gourd, Padmavathi *et al*. (2002) in tomato, Patil *et al.* (2002) in onion and Narayanamma *et al.* (2004) in carrot. Interactive effect of treatment shows that increase in FYM /vermicompost and mineral nutrients resulted in increased plant height, number of leaves, fresh and dry weight of leaves as compared to control. This clearly shows that combined application of FYM/vermicompost and mineral nutrients is more beneficial as compared to the individual. Application of organic manure in the form of FYM increased the yield attributes and yield. Such increase may be due to release of macro and micronutrients during the course of microbial decomposition (Singh and Ram, 1982). Organic matter also function as a source of energy for soil micro- flora which bring about the transformation of inorganic nutrients held in soil or applied in the form of fertilizers in a form that is readily utilized by growing plants. FYM/vermicompost also improved the physical properties of the soil (Singh and Singh, 1974). The beneficial response of FYM/vermicompost to yield might also be attributed to the availability of sufficient amount of plant nutrients through out the growth period of crop resulting in better uptake, plant vigour and yield (Prasad and Sinha, 1995; Brar and Pasricha, 1998).

The application of mineral nutrient fertilizer alone or in combination increased the yield attributes and yield but the response was more when more number of nutrients were applied through mineral mixture. This was due to the fact that application of fertilizer alone had supplied only one or two nutrients while combined use of macro and micronutrient fertilizers had provided, all the essential nutrients in proper amount, required by the plant for its growth and development. Application of more nutrients through fertilizers might have covered the deficiency and resulted into enhanced yield attributes and yield. These findings are in agreement with those of Iswari *et al.* (1987) in wheat; Reddy *et al.*(1998) in pea, Akbari *et al.* (1999) and Ahmed and Reddy (2000) in onion.

5.3. Quality attributes

5.3.1 Effect of plant geometry

It was observed that plant spacing had non-significant effect on total soluble solids, sulphur content, allyl-propyl-disulphide and vitamin “C” content. Similar results were also reported by Naik and Hosamani (2000) in onion.

Significant increase in nitrogen, phosphorus and potassium content in bulb with wider plant spacing i.e., 45 X 10 cm and 45 X 15 cm was noticed (Table 4.18 to 4.20). The positive influence of the wider spacing on N, P and K content of bulb appeared to be due to improved nutritional environment both in the root zone and the plant system. The competitive ability of plants in a community very greatly depend upon the density of plants per unit area. Higher plant density, adversely affect the plant growth and development thus, wider spacing increased availability of nutrients, light and moisture to plant coupled with increased metabolic activity at the cellular level probably might have increased the nutrients uptake and accumulation in the vegetative plant parts. Increased accumulation of nutrients especially in vegetative plant parts possibly with improved metabolism led to greater translocation of these nutrients to repository organ (bulb) of the crop. Significant increase in quality attributes with wider spacing was earlier reported by Bartos and Holik (1990) and Naruka (2000) in garlic and Jha *et al.* (2000) in onion.

5.3.2. Effect of fertility levels

Increasing levels of fertility levels up to 50 per cent recommended dose of NPK along with vermicompost 2.5 t ha^{-1} increased N, P and K content of onion bulb under study (Table 4.18, 4.19 and 4.20). The influence of nitrogen fertilization on N, P and K content of bulb appeared to be due to improved nutritional environment both in the root zone and the plant system. Thus, adequate supply of N, P and K early in the crop season increased the availability of nutrients to the root zone coupled with increased metabolic activity at cellular level might have increased the nutrients uptake and accumulation in the vegetative plant parts. The higher nutrient contents in bulb also seems to be due to higher functional activity of roots for longer duration under this treatment. The increase in N, P and K content in bulb were also observed by Lal *et al.* (1988), Vachhani and Patel (1993), Singh *et al.* (1996), Yadav (2000) and Sharma *et al.* (2003).

Application of NPK significantly increased the allyl-propyl-disulphide in onion bulb (Table 4.16). Besides, increase in bulb yield slightly increasing trend in content of allyl-propyl-disulphide was noticed due to N application. There results were in close agreement with those of E1 –oksh *et al.* (1993) and Singh *et al.* (1996). Correlation studies also revealed positive and significant relationship between pungency, N content and bulb yield.

TSS content significantly increased with the nitrogen application. Nitrogen helped in vigorous vegetative growth and imparted deep green colour to the foliage which favoured photosynthetic activity of the plants so there was greater accumulation of food material i.e., carbohydrates in the bulb which synthesized to saccharides and there was increase in TSS content. It showed a positive correlation with yield (Table 4.27). The similar results have also been reported by Singh *et al.* (1989), Pandey *et al.* (1991), Vachhani and Patel (1993) and Thabet *et al.* (1994).

Potassium induces tolerance against abiotic stresses and helps plant to fight against the adverse conditions. Secondly, the potassium concentration in the soil solution might have gone down due to leaching losses, fixation and high initial uptake by plant. Therefore, higher dose of potassium increased N, P, K and S content in bulb. Further, potassium activates the fat producing enzymes, which enhances the oil content. The increase in N, P, K , S, TSS and allyl- propyl- disulphide content due to application of potassium have also been observed by Duque *et al.*(1989), Singh *et al.* (1989) and Kopsell and Randle (1997).

The beneficial effect of FYM/vermicompost in increasing the content of nitrogen in bulb and leaves might be attributed to its direct supply of nitrogen. Moreover, FYM/ vermicompost after decomposition might have released macro and micro-nutrients, which increases the availability of nutrients to the soil, plant system and thus increased the nutrient content in plants. The higher nutrient availability enhanced photosynthesis and their translocation to different plant parts resulting into higher concentration of nutrient particularly, nitrogen. Similar findings have also been observed by Mahajan *et al.* (1999), Singh and Singh (2000) and Sreenivas *et al.* (2000).

The phosphorus content was increased significantly with increasing level of FYM/vermicompost. These findings were in agreement with those of Havlin *et al.* (1999) who reported that organic compounds in soil increased phosphorus availability by i) the formation of organo-phosphate complexes that are more easily assimilated by plants and ii) increasing the quantity of organic phosphorus which mineralized to inorganic phosphorus. Similar findings have been earlier reported by Vachhani and Patel (1993) and Sharma *et al.* (2003).

5.4. Uptake and availability of nutrients

5.4.1 Effect of plant geometry

It was observed that wider plant spacing increased N, P and K uptake and available soil N, P_2O_5 and K_20 significantly (Table 4.21, 4.22, 4.23, 4.24, 4.25 and 4.26). This might be due to the fact that wider plant spacing facilitated lesser competition for space, nutrients and there was more availability of light to the plant. The content and uptake of any nutrient in the plant is directly related to its availability in the feeding zone and growth of plants. Thus, increase in doses of nitrogen, phosphorus and potassium might have resulted in higher content and uptake of these nutrients. The results of the present investigation were in close agreement with the findings of Lal *et al.* (1988), Duque *et al.* (1989) and Patel *et al.* (1992).

5.4.2 Effect of fertility levels

The significant increase in N, P and K uptake in onion bulb with the increasing levels of fertility (NPK) was due to the effect of higher yield along with higher N, P and K content in bulbs. The content and uptake of any nutrient in the plant is directly related to its availability in the feeding zone and growth of plant. Thus, increase in the doses of N, P and K might have resulted in higher content and uptake of these nutrients in onion. The results were in close agreement with the findings of Lal *et al.* (1988),Duque *et al.*(1989), Shanthi and Balakrishnan (1989) and Patel *et al.* (1992). Further, the application of 50 per cent recommended dose of NPK along with vermicompost 2.5 t ha^{-1} significantly increased its availability in soil. The probable explanation of this result was due to better utilization of native N, P and K with increase in rate of N, P and K application. Similar build up of native nitrogen and supplementary addition was also noted by Singh (1984) in mustard. Similarly, the application of 50 per cent recommended dose of NPK alongwith vermicompost 2.5 t ha^{-1} also increased the availability of potassium (Table 4.26) in soil after harvesting. The favourable effect of nitrogen fertilization in improving the K status is an outcome of increased proliferation of roots and microbial activity, which in turn have released the organic acids lowering down the pH of soil and releasing the native potassium from the soil (Mayura and Ghosh, 1972).

The application of mineral nutrients increased the content and uptake of nitrogen because the experimental soil was light in texture, low in organic mater and nitrogen status. The application of mineral nutrients supplied the nitrogen as well as other nutrients and increased its availability to the plants resulting into higher absorption and uptake of nitrogen by plants. Similar findings were also observed by Kuligod *et al.* (1994) in wheat and Dwivedi *et al.* (2001) in maize.

The increased uptake of nitrogen with increasing number of mineral nutrients was due to added supply of nutrients and an account of proliferous root system developed under balanced nutrient application resulted in better absorption of water and nutrients. Miller *et al.* (1987) also reported significant improvement in the uptake of nitrogen with the application of mineral nutrient in conjunction with FYM under different soils, crops and climatic conditions.

The data presented in Table 4.23 show that the P uptake by bulb and leaves increased with increasing application of mineral mixture. This is due to the fact that the uptake is the product of yield and mineral content although, the content was decreased slightly with the application of mineral nutrients but the extent of increase in yield was more, perhaps this resulted into higher P uptake by bulb and leaves with the application of mineral mixture as compared to control. In the present investigation N, P and K uptake also had a positive and significant correlation with yield.

The uptake of potassium increased significantly with the increase in number of minerals in a mineral mixture. An increase in uptake of potassium by the crop was attributed to the fact that micro-nutrients were involved in many enzymatic activities and synthesis of growth hormone which resulted in better root growth and absorption of nutrients. Havlin *et al.* (1999) and Singh *et al.* (2001) reported an increase in potassium uptake with increase in number of minerals in a mineral mixture.

5.5 Interaction effects

5.5.1 Interaction effects of plant geometry and fertility levels

The interaction effect of spacing and fertility level was found significant for equatorial diameter, fresh weight of bulb, bulb yield and phosphorus content and also for nitrogen, phosphorus and potassium uptake. Maximum values for equatorial diameter (Table 4.7b) and fresh weight of bulb (Table 4.11b) were observed when 50 per cent recommended dose of NPK (50:25:50 kg NPK ha^{-1}) along with vermicompost 2.5 t ha^{-1} (T_7) was applied in conjunction with the spacing of 45 X10 cm (S_3). However, the maximum bulb yield (Table 4.13b), phosphorus content (Table 4.19b), nitrogen uptake (Table 4.21b), phosphorus uptake (Table 4.22b) and potassium uptake (Table 4.23b) were observed in the treatment 50 per cent recommended dose of NPK plus vermicompost 2.5 t ha^{-1} (T_7) along with plant spacing 30 X 10 cm (S_1). Although, both fertility level and plant spacing independently brought significant variation in yield attributes but interaction of S_1 X T_7 showed that response of fertility level was governed by plant spacing and vice-versa. Thus, exhibiting their inter dependence for obtaining higher value of these parameters. Hence, it is clear that application of T_7 fertility level (50 % recommended dose of NPK plus vermicompost 2.5 t ha^{-1}) in combination with S_1 (30 x 10 cm) plant spacing influenced the availability and uptake of nutrients and ultimately the growth and development of plant as obtained in the present study. The bulb yield, P content, N, P and K uptake was maximum in the treatment combination S_1T_7 during both the years. This might be due to accommodating more number of plants per unit area and supply of proper nutrients. These findings corroborate with the findings of Sreenivas *et al*. (2000), Padmavathi *et al.* (2002). and Sharma *et al.* (2003).

Economics

Benefit: cost ratio of different treatment combinations presented in table 4.27 clearly revealed that S_3T_7 resulted in maximum net profit of Rs 155721.00 with a B:C ratio of 4.85:1 followed by S_4T_7 with net profit of Rs 145625.00 and a B:C ratio 4.47:1 However, the maximum bulb yield was recorded in S_1T_7 treatment combination but with a lower grade compared to S_3T_7 and S_4T_7 and fetched lesser price of the bulbs

6. SUMMARY AND CONCLUSION

The results of the experiment " Effect of crop geometry and fertility levels on growth, yield and quality of *Kharif* onion (A*llium cepa* L.) cv. N-53 in semi- arid conditions" conducted during 2001and 2002 presented and discussed in the preceding sections are being summarized as under.

6.1 Plant geometry

1. Among various plant spacings tried, the spacing S_4 (45x 15 cm) exhibited maximum number of leaves and fresh weight of leaves at harvest but it was at par with S_3 (45 x 10 cm). However, the maximum dry weight of leaves was recorded in S_3 (45 x 10 cm) spacing.

2. Maximum neck length and thickness of scales were recoded in spacing S_4 (45 x 15 cm). Similarly equatorial diameter and volume of bulb were maximum with S_4 (45 x 15 cm) plant spacing but it was at par with S_3 (45 x 10 cm). Maximum polar diameter, number of scales bulb^{-1} and fresh weight of bulb were obtained with S_3 (45 x 10 cm). While maximum bulb yield was recorded with S_1 (30 x 10 cm) spacing.

3. Maximum nitrogen and phosphorus content in bulb, available N, P and K were recorded with S_3 (45 x 10 cm) whereas maximum N, P and K uptake were in S_1 (30 x 10 cm).

6.2 Fertility Levels

1. Maximum plant height was recorded in T_8 (75 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}). Whereas, maximum fresh and dry weight of leaves at harvest were recorded with T_7 (50 % recommended does of NPK + vermicompost 2.5 t ha^{-1}).
2. The maximum neck length was recorded with T_8 whereas, equatorial and polar diameter, number of scales $bulb^{-1}$, thickness of scale, fresh weight and volume of bulb and bulb yield ha^{-1} were recorded with T_7.
3. The maximum TSS, N content and uptake in bulb were recorded with $T_{8.}$ Whereas maximum sulphur content, pungency, vitamin C content, P content and uptake and K uptake in bulb were recorded with T_7. The maximum available N, P and K in soil after harvesting were also recorded with T_7.

6.3 Interaction effect of plant geometry and fertility levels

The maximum equatorial diameter was recorded with S_4T_7 (45 x 15 cm spacing + 50 % recommended does of NPK along with vermicompost 2.5 t ha^{-1}) while maximum fresh weight of bulb was found in S_3T_7 treatment combination. Though it was statistically at par with $S_4T_{7.}$ Whereas, maximum bulb yield and nitrogen and phosphorus uptake in bulb were recorded with S_1T_7 (30 x 10 cm + 50 % recommended does of NPK along with vermicompost 2.5t ha^{-1}).

6.4 Economics

The highest net returns of Rs 155721.00 was recorded under the treatment combination S_3T_7 with highest B.C. ratio (4.85:1) as compared to the lowers net return of Rs 42218.00 ha^{-1} in S_4T_1 with B.C. ratio of 1.28:1.

CONCLUSION

On the basis of results emanated from the present investigation conducted during *kharif* 2001 and 2002, it is concluded that application of 50 per cent recommended dose of NPK and vermicompost 2.5 t ha^{-1} with 45 x 10 cm crop geometry proved best in respect of maximum growth and productivity. The maximum net return with higher B:C ratio was obtained in above treatment combination (4.85:1).

Effect of crop geometry and fertility levels on growth, yield and quality of kharif onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions

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Abstract

The field experiment to study the "Effect of crop geometry and fertility levels on growth, yield and quality of *kharif* onion (*Allium cepa* L.) cv. N-53 in semi-arid conditions was conducted in loamy sand soil of the Horticulture Farm, S.K.N. College of Agriculture, Jobner during *kharif* season of 2001 and 2002. The experiment, comprising of 32 treatment combinations replicated four times, laid out in split-plot design with four spacings 30 x 10 cm, 30 x 15 cm, 45 x 10 cm and 45 x 15 cm in main plots and different fertility levels (control, 75%, 100% and 125% recommended dose of NPK, vermicompost 2.5 t /ha, and vermicompost 2.5 t/ha with 25 %, 50 % and 75 % recommended dose of NPK) as sub plots.

Plant spacing 45 x 10 cm was superior over different spacings in relation to growth attributes, number of leaves plant^{-1}, fresh and dry weight of leaves, yield attributes (neck thickness, neck length equatorial diameter, polar diameter, number of scales bulb^{-1}, fresh weight and volume of bulb) and quality attributes (nitrogen, phosphorus and potassium content in bulb). However, yield per hectare was maximum under 30 x 10 cm spacing due to more number of plants accommodated per unit area.

50 % recommended dose of NPK + vermicompost 2.5 t ha^{-1}, significantly improved the growth (plant height, number of leaves plant^{-1}, fresh and dry weight of leaves at harvest), yield attributes (neck length, equatorial diameter, polar diameter, number of scales bulb^{-1}, thickness of scales, fresh weight and volume of bulb and yield, quality attributes (sulphur content, pungency, vitamin 'C' and N, P and K content in bulb) plant and nutrient status of *kharif* onion.

The maximum net return with higher B:C ratio (4.85:1) was obtained in treatment combination 45 x 10 cm crop geometry with 50 % recommended dose of NPK along with vermicompost 2.5 t ha^{-1}.

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Response of Integrated nutrient management on the growth, yield and quality of *Kharif* onion (*Allium cepa* L.)

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ABSTRACTS

The field experiment to study the "Effect of fertility levels on growth, yield and quality of *Kharif* onion" was conducted at Horticulture farm, S.K.N. College of Agriculture, Jobner during *Kharif* 2001 and 2002. The experiment comprising 8 fertility levels (Control, 75 %, 100%, and 125%) recommended dose of NPK vermicompost 2.5 t ha^{-1} and vermicompost 2.5 t $ha^{-1}$with 25 %, 50 % and 75% recommended dose of NPK). The application of 50 per cent recommended dose of NPK +vermicompost 2.5 t ha^{1} significantly improved the plant height, number of leaves at harvest, equatorial diameter thickness of scale, volume of bulb, yield and TSS, vitamin "C" and allyl propyl disulphide content.

Key words : Recommended dose of NPK, Vermicompost, Yield

INTRODUCTION

Onion is cultivated in rabi season but early *kharif* and late *kharif* crops are also taken in various parts of India. During October – November there is shortage of onion in the market, which lends to heavy prices. Therefore, production of onion in *kharif* season is more important to continuous supply of onion round the years. Integrated nutrient. supply approach is not only the liable way for obtaining fairly high productivity with substainal fertilizer economy but a concept of ecological soundness leading to sustainable agriculture (Swaminathan, 1988). Use for vermicompost in conjunction with chemical fertilizer has been found to be promising not only in maintaining and sustaining higher productivity but also providing stability in crop production. The information on the balanced use of chemical fertilizers alongwith vermicompost for *kharif* season onion in the state in very scare. Hence an experiment was conducted to determine best level of inorganic and organic fertilizer for enhancing the growth, yield and quality of onion.

MATERIALS AND METHODS

An experiment was conducted during *kharif* seasons of 2001 and 2002 at horticulture farm, S.K.N. College of Agriculture, Jobner in split plot design with four replication.To obtain good quality of onion sets they are prepared at there and variety N-53were taken. The seeds were sown in well prepared nursery bed in the first week of February at closer spacing. Then sets were lifted in the first week of May from the nursery beds and tops were removed and graded. The fertility treatment were like as; control, 75 %, 100 % and 125 % recommended dose of NPK, vermicompost 2.5 t ha^{-1} and vermicompost 2.5 t ha^{-1} alongwith 25 %, 50 % and 75 % recommended dose of NPK. The recommended dose of NPK was 100 kg N, 50 kg P_2O_5 and 100 kg MOP and calculated according to treatment wise. The full dose of phosphorus and potash and half dose of nitrogen were given at the time of transplanting of sets, and remaining half dose of nitrogen was given 30 days after transplanting and vermicompost was supplied before the planting of sets. The sets were planted 45 x 10 cm distance and both sides of ridges in Aug. month. All the observation were taken and harvesting was done in last week of December. The total soluble solids was determined with the help of hand refractometer at the time of harvesting of bulb. The vitamin "C" content of bulb was determined by diluting the known volume of onion juice with 3 per cent meta-phosphoric acid and titrating with 2,6 dichloro phenyl indophenol solution (A.O.A.C., 1960), till the faint pink colour was obtained. Allyl propyl disulphide content in onion bulb was determined as pyruvic acid (Hort and Fisher, 1971).

RESULT AND DISCUSSION

It is revealed from the data (Tabel-1) that the plant height, number of leaves $plant^{-1}$ at harvest of onion were significantly affected with different fertility levels. The maximum plant height (53.16cm), with maximum number of leaves (11.91) were obtain with 50 per cent recommended dose of NPK alongwith vermicompost 2.5 t ha^{-1} which was at par with 75 per cent recommended dose NPK along with vermicompost 2.5 t ha^{-1}. The improvement in plant height, number of leaves with the application of vermicompost might be due to better moisture holding capacity & supply and availability of major and micro nutrient due to favourable soil condition (Reddy *et al.*, 1998). In case of vermicompost the earthworm carts helps in improvement the soil fertility and availability & nutrients besides some growth stimulating substances excreted by earthworm into their carts. (Senapati *et al.*, 1985).

The yield attributes charters of onion was significantly influenced with different fertility level. The maximum equatorial diameter (5.62 cm), thickness of scales (0.274 cm), volume of bulb (56.03 cc) and yield (224.29 q ha^{-1}) were recorded with 50 per cent recommended dose of NPK alongwith vermicompost 2.5 t ha^{-1}. However neck length (6.40 cm) and fresh weight of bulb (95.14 g) were maximum in 75 % recommended dose NPK plus vermicompost 2.5 t ha^{-1}but it was at par with (T_7). The present trend of increase in bulb yield and yield attributes with 50 per cent recommended dose of NPK along with vermicompost 2.5 t ha^{-1} is in close conformity with findings of Mahendran and Kumar (1997), Patil *et al.*, (2002), Application of organic manure in the form of vermicompost increased the yield attributes and yield. Such increase may be due to release of macro and micronutrient, during the course of microbial decomposition (Singh and Ram, 1982). The beneficial response of FYM vermicompost to yield might also be attributed to availability of sufficient amount of plant nutrients throughout the growth period of crop uptake, plant vigour and yield (Brar and Pasricha, 1998).

The data presented in Tabel-1 revealed that application of 75 per cent recommended dose of NPK alongwith vermicompost 2.5 t ha^{-1} affected the TSS, (12.16), Allyl propyl disulphide (7.23) and vitamin “C” (9.68mg/100 g) content but it was at par with 50 per cent recommended dose of NPK plus vermicompost 2.5 t ha^{-} . An increased in NPK significantly vitamin "C" content, which was due to helped in vigorous vegetative growth and imparted green colour to foliage which favoured photosynthetic activity of plant so there was greater accumulation of food material. The similar results have been also been reported by Singh *et al.*, (1989), Thabet *et al.*, (1994) and Singh *et al.*, (1996).

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Table :-1 Response of integrated nutrient management on growth , yield and quality of *Kharif* onion

Treatment	Plant height (cm)	Number of leaves per plant at harvest	Neck thickness (cm)	Equatorial diameter (cm)	Thickness of scale (cm)	Fresh weight of bulb (g)	Volume of bulb (cc)	Yield (q per ha)	T.S.S (%)	Allyl propyl disulphide	Vitamin C (mg/100g)
Control	38.42	6.61	5.73	4.07	0.188	56.59	41.63	128.76	12.04	6.57	9.20
75 % recommended dose of NPK	52.29	9.80	5.81	4.80	0.212	69.27	48.05	158.51	12.09	6.67	9.23
100 % recommended dose of NPK	52.96	10.67	5.94	5.34	0.248	79.53	53.74	182.03	12.15	6.95	9.58
125 % recommended dose of NPK	52.82	10.36	6.08	5.25	0.229	76.39	53.50	174.97	12.20	6.81	9.44
Vermicompost 2.5 t ha^{-1}	52.47	10.08	6.21	5.15	0.221	71.11	51.18	161.27	12.22	6.74	9.36
25 % recommended dose of NPK+ vermicompost 2.5 t ha^{-1}	52.99	11.17	6.28	5.43	0.263	86.48	54.37	198.10	12.27	7.01	9.62
50 % recommended dose of NPK+ vermicompost 2.5 t ha^{-1}	53.11	11.91	6.32	5.62	0.274	94.78	56.03	224.29	12.32	7.23	9.66
75% recommended dose of NPK+ vermicompost 2.5 t ha^{-1}	53.16	11.63	6.40	5.60	0.272	95.14	55.15	214.54	12.36	7.07	9.68
SEm$\pm$	0.654	0.121	0.067	0.054	0.0024	0.439	0.664	2.605	0.083	0.067	0.067
CD at 5 %	1.832	0.338	0.187	0.153	0.0066	1.230	1.860	7.301	0.232	0.187	0.188

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APPENDIX-I

Analysis of variance (MSS) for plant height (cm), and number of leaves $plant^{-1}$,fresh and dry weight of leavesat harvest

Source of variance	d.f.	Plant height		Number of leaves per plant at harvest		Fresh weight of leaves at harvest		Dry weight of leaves at harvest	
		2001	2002	2001	2002	2001	2002	2001	2002
Replication	3	43.779	50.784	0.144	0.115	24.98	25.92	0.64	0.17
Spacing	3	0.155	0.975	3.949*	4.142	309.23**	269.89**	1.21*	0.70*
Error (a)	9	28.569	26.794	0.949	0.918	10.26	9.00	0.29	0.17
Treatment	7	416.276**	417.262**	43.559**	44.263**	888.71**	907.69**	12.62**	12.89**
S x T	21	0.052	0.249	0.0035	0.0074	0.80	0.90	0.003	0.003
Error (b)	84	13.16292	14.163	0.4712	0.4607	6.21	5.51	0.13	0.149

* Significant at 5% level
** Significant at 1% level

APPENDIX-II

Analysis of variance (MSS) for Neck thickness, neck length (cm), equatorial diameter(cm) and polar diameter(cm) of bulb

Source of variance	d.f.	Neck thickness		Neck length		Equatorial diameter		Polar diameter	
		2001	2002	2001	2002	2001	2002	2001	2002
Replication	3	0.0019	0.0020	0.1886	0.2598	0.0782	0.0783	0.0819	0.1940
Spacing	3	0.0316**	0.0577**	1.1492*	1.0329*	0.8020**	0.8756**	0.3355*	0.4168*
Error (a)	9	0.0038	0.0040	0.2671	0.2314	0.0974	0.1153	0.0849	0.1035
Treatment	7	0.5715**	0.5919**	0.9850**	0.9590**	4.3311**	4.1051**	4.1794**	4.1215**
S x T	21	0.0011	0.0018	0.0016	0.0015	0.1780*	0.2025*	0.0059	0.0069
Error (b)	84	0.0034	0.0038	0.1374	0.1488	0.0888	0.1008	0.0751	0.0923

* Significant at 5% level
** Significant at 1% level

APPENDIX-III

Analysis of variance (MSS) for number of scales $bulb^{-1}$, thickness of scales (cm), fresh weight(g) and volume(cc) of bulb

Source of variance	d.f.	Number of scales per bulb		Thickness of scales		Fresh weight		Volume of bulb	
		2001	2002	2001	2002	2001	2002	2001	2002

Replication	3	0.2569	0.2466	0.00048	0.00078	18.12	18.82	11.58	13.96
Spacing	3	0.4700*	0.4692*	0.0013**	0.00108**	64.57*	54.32*	85.47*	88.40*
Error (a)	9	0.1181	0.1147	0.00024	0.00026	12.72	13.30	17.61	18.23
Treatment	7	9.1231**	9.9717**	0.01470**	0.01634**	2941.24**	2716.22**	362.81**	369.35**
S x T	21	0.0954	0.0083	0.00002	0.00004	11.51*	116.54**	0.23	0.23
Error (b)	84	0.1076	0.1089	0.00020	0.00016	5.72	6.60	13.34	14.84

* Significant at 5% level
** Significant at 1% level

APPENDIX-IV

Analysis of variance (MSS) for bulb yield(q ha^{-1}), TSS(%) and vitamin "C" (mg/100 g) content

Source of variance	d.f.	Bulb yield		TSS		
		2001	2002	2001	2002	2001
Replication	3	939.59	988.41	0.437	0.174	0.742
Spacing	3	108788.43**	110880.96**	0.014	0.019	0.064
Error (a)	9	408.81	420.37	0.527	0.340	0.315
Treatment	7	16042.67**	15735.42**	0.195	0.199	0.582**
S x T	21	490.57*	455.72*	0.0002	0.0006	0.002
Error (b)	84	214.08	220.09	0.2061	0.2340	0.147

* Significant at 5% level
** Significant at 1% level

APPENDIX-V

Analysis of variance (MSS) for sulphur content(%), pungency allyl propyl disulphide(mg/100 g), nitrogen and phosphorus content (%)

Source of variance	d.f.	Sulphur content		Pungency allyl propyl disulphide		Nitrogen content		Phosphorus content	
		2001	2002	2001	2002	2001	2002	2001	2002
Replication	3	0.00053	0.00008	0.1886	0.2598	0.00048	0.00009	0.00039	0.00037
Spacing	3	0.00085	0.00065	0.0832	0.0893	0.00425*	0.00372*	0.00195*	0.00227*
Error (a)	9	0.00106	0.00095	0.2671	0.2314	0.00092	0.00092	0.00039	0.00043
Treatment	7	0.00507**	0.00529**	0.8029**	0.7515**	0.15944**	0.16176**	0.08608**	0.09508**

S x T	21	0.00002	0.00002	0.0013	0.0020	0.00036	0.00029	0.00047	0.00041
Error (b)	84	0.00059	0.00050	0.1374	0.1488	0.00059	0.00050	0.00033	0.00033

* Significant at 5% level
** Significant at 1% level

APPENDIX-VI

Analysis of variance (MSS) for potassium content(%), nitrogen, phosphorus and potassium uptake(q ha^{-1})

Source of variance	d.f.	Potassium content		Nitrogen uptake		Phosphorus uptake		Potassium uptake	
		2001	2002	2001	2002	2001	2002	2001	2002
Replication	3	0.00164	0.0117	541.51	508.17	37.85	44.84	1454.60	1500.99
Spacing	3	0.00926*	0.00925*	61511.56**	64152.96**	11719.63**	13489.73**	122389.84**	125697.56**
Error (a)	9	0.00235	0.00208	385.96	397.07	101.60	113.56	960.39	965.83
Treatment	7	0.00413*	0.00390**	23294.51**	23559.10**	9140.73**	9856.81*	22576.22*	22181.74**
S x T	21	0.00022	0.00025	565.11**	561.69**	252.83**	253.84**	621.16	587.85
Error (b)	84	0.00113	0.00094	148.08	153.19	35.19	37.65	355.73	345.56

* Significant at 5% level
** Significant at 1% level

APPENDIX-VII

Analysis of variance (MSS) for available nitrogen, phosphorus and potassium (q ha^{-1}) in soil after harvest

Source of variance	d.f.	Available nitrogen		Available phosphorus		Avail
		2001	2002	2001	2002	2001
Replication	3	51.42	72.08	0.1346	1.35	27.03
Spacing	3	817.54*	993.92*	5.59*	4.90*	476.92*
Error (a)	9	148.29	177.45	1.13	1.00	110.30
Treatment	7	2620.34**	2326.12**	33.09**	26.79**	1613.06**
S x T	21	54.53	114.15	0.26	0.59	0.66
Error (b)	84	95.11	114.63	0.94	0.88	85.15

* Significant at 5% level
Significant at 1% level

APPENDIX-VIII

Pooled analysis of variance (MSS) for plant height(cm), number of leaves per plant at harvest, fresh and dry weight(g) of leaves at harvest, neck thickness(cm) and neck length (cm)

Source of variance	d.f.	Plant height	Number of leaves per plant	Fresh weight	Dry weight of leaves	Neck thi
Year	1	0.158	0.185	0.08	0.001	0.041
Replication	6	47.281	0.129	25.45	0.403	0.00
S	3	0.703	8.091*	573.17**	1.827**	0.087
Y x S	3	0.427	0.00128	5.95	0.087	0.00
Error (a)	18	27.682	0.9334	9.63	0.2313	0.00
T	7	833.431**	87.816**	1796.30**	25.5068**	1.158
Y x T	7	0.107	0.0058	0.09	0.0014	0.00
S x T	21	0.182	0.0086	1.66	0.0054	0.00
Y x S x T	21	0.119	0.0023	0.05	0.0007	0.00
Error (b)	168	13.666	0.4659	5.86	0.1406	0.00

* Significant at 5% level
** Significant at 1% level

APENDIX-1X

Pooled analysis of variance (MSS) for Equatorial diameter(cm), polar diameter (cm), number of scales per bulb, thickness of scales (cm), fresh weight (g) and volume (cc) of bulb

Source of variance	d.f.	Equatorial diameter	Polar diameter	Number of scales per bulb	Thickness of scales	Fresh weight of bu
Year	1	0.0875	0.1406	0.9216*	0.00109	0.79
Replication	6	0.0782	0.1379	0.2517	0.00063	18.47
S	3	1.6749**	0.7496**	0.8984**	0.00238**	111.01**
Y x S	3	0.0027	0.0027	0.0407	0.00001	5.87
Error (a)	18	0.1064	0.0942	0.1164	0.00025	13.01
T	7	8.4321**	8.3007**	19.0485**	0.03102**	5626.47**
Y x T	7	0.0041	0.0012	0.04631	0.00003	30.99**
S x T	21	0.3762**	0.0114	0.0624	0.00004	98.46**
Y x S x T	21	0.0043	0.0014	0.0413	0.00001	29.60
Error (b)	168	0.0948	0.0837	0.1082	0.00018	6.16

* Significant at 5% level
** Significant at 1% level

APPENDIX-X

Pooled analysis of variance (MSS) for bulb yield (q ha^{-1}), TSS(%), vitamin 'C'(mg/100 g), sulphur content(%) and allyl propyl disulphide(mg/100 g)

Source of variance	d.f.	Bulb yield	TSS	Vitamin 'C'	Sulphur content
Year	1	26.60	0.058	0.054	0.00070
Replication	6	964.00	0.306	0.741	0.00030
S	3	219662.74**	0.033	0.118	0.00149

Y x S	3	6.66	0.0002	0.002	0.00001
Error (a)	18	414.59	0.4333	0.305	0.00101
T	7	31769.58**	0.393*	1.168**	0.01036*
Y x T	7	8.51	0.001	0.0002	0.00001
S x T	21	939.84**	0.0006	0.0026	0.00004
Y x S x T	21	6.46	0.0002	0.00014	0.00001
Error (b)	168	217.09	0.2198	0.1439	0.00054

* Significant at 5% level
** Significant at 1% level

APPENDIX-XI

Pooled analysis of variance (MSS) for nitrogen, phosphorus and potassium content(%) and NPK uptake (kg ha^{-1})

Source of variance	d.f.	Nitrogen content	Phosphorus content	Potassium content	Nitrogen uptake	Phosphorus uptak
Year	1	0.00205	0.01613**	0.00048	152.66	689.34*
Replication	6	0.00028	0.00038	0.00141	524.84	41.35
S	3	0.00795**	0.00411**	0.01850**	125647.98**	25176.78**
Y x S	3	0.00002	0.00011	0.00001	16.54	32.57
Error (a)	18	0.00092	0.00041	0.00221	391.52	107.58
T	7	0.32017**	0.18033**	0.00801**	46848.25**	18963.81**
Y x T	7	0.00003	0.00083*	0.00001	5.37*	33.73
S x T	21	0.00064	0.00079*	0.00046	1122.22**	503.13**
Y x S x T	21	0.00001	0.00009	0.00001	4.58	3.54
Error (b)	168	0.00054	0.00033	0.00104	150.64	36.42

* Significant at 5% level
** Significant at 1% level

Annexure-I

Climatic variables for the period of investigation (04 August to 27 September 2000-2001 and 2001-2002)

Week Duration	No.	Temperature (^{0}C)				R.H. (%)		Open P Evapora (mm)
		Maximum		Minimum		2001	2002	2001
		2001	2002	2001	2002			

1	04 Aug. to 10 Aug	33.2	38.8	24.7	26.7	65	75	5.4
2	11 Aug. to 17 Aug.	32.7	35.9	24.1	26.3	81	63	3.2
3	18 Aug. to 24 Aug.	31.9	35.5	25.0	26.0	75	58	4.0
4	25 Aug. to 31 Aug.	33.6	36.2	23.3	25.5	63	60	5.4
5	01 Sept. to 06 Sept.	33.6	35.1	23.0	25.3	63	59	6.5
6	07 Sept. to 13 Sept.	34.9	35.9	22.5	24.3	59	62	6.0
7	14 Sept. to 20 Sept.	57.7	36.0	22.2	22.9	55	49	5.2
8	21 Sept. to 27 Sept.	36.8	36.3	21.0	22.1	47	51	6.9

Table 4.27 Correlation among different parameters and nutrients content and uptake in onion.

Character	Fresh weight of leaves	Volume of bulb	Fresh weight of bulb	No. of scale	Neck thickness	Eqatorial diameter	Thickness scales	TSS	Vit. C	Pungency	N content	P contnet	K content	S content	N uptake	P uptake	K uptake	Bulb yield
Fresh weight of leaves	1	0.926**	0.734**	0.886**	0.648**	0.874**	0.749**	.733**	0.688**	0.717**	0.957**	0.599**	0.657**	0.874**	0.357*	0.329	0.173	0.134
Volume of bulb		1	0.857**	0.951**	0.769**	0.938**	0.888**	0.862**	0.882**	0.871**	0.936**	0.754**	0.765**	0.968**	0.422*	0.453**	0.250	0.204
Fresh weight of bulb			1	0.932**	0.827**	0.823**	0.939**	0.887**	0.920**	0.929**	0.840**	0.874**	0.633**	0.926**	0.674**	0.751**	.0.551**	.509**
No. of scale				1	0.807**	0.890**	0.931**	0.877**	0.907**	0.923**	0.947**	0.838**	0.700**	0.978**	0.613**	0.648**	0.463**	.419*
Neck thickness					1	0.706**	0.833**	0.973**	0.794**	0.808**	0.726**	0.795**	0.601**	0.826**	0.435*	0.535**	0.309	.269
Equatorial diameter						1	0.868**	0.843**	0.845**	0.821**	0.893**	0.715**	0.680**	0.921**	0.424*	0.443*	0.250	.210.
Thickness scales							1	0.886	0.947**	0.942**	0.834**	0.891**	0.682**	0.948**	0.530**	0.226**	0.389*	0.346
TSS								1	0.857**	0.861**	0.813**	0.799**	0.640**	0.895**	0.481**	0.556**	0.338	0.296
Vit. C									1	0.950**	0.779**	0.866**	0.771**	0.939**	0.544**	0.638**	0.422*	0.373*
Pungency										1	0.778**	0.940**	0.778**	0.943**	0.523**	0.664**	0.405*	0.354*
N content											1	0.659**	0.585**	0.918**	0.564**	0.513**	0.393*	0.358*
P content												1	0.676**	0.857**	0.529**	0.729**	.440*	0.395*
K content													1	0.779**	0.050	0.188	-0.068	-0.128
S content														1	0.522**	0.583**	0.365*	0.316
N uptake															1	0.936**	0.979**	.970**
P uptake																1	0.923**	0.904**
K uptake																	1	0.393*
																		1

* Significant at 5% level

** Significant at 1% level

APPENDIX-XII

Pooled analysis of variance (MSS) for available nitrogen, phosphorus and potassium content in soil after harvest

Source of variance	d.f.	Available N	Available P_2O_5	Available K_2O
Year	1	16.63	0.05	53.77
Replication	6	61.75	0.74	21.39
S	3	1805.21**	10.24**	868.23**
Y x S	3	6.25	0.25	8.33
Error (a)	18	162.87	1.06	98.31
T	7	4940.93**	59.28**	3207.99**
Y x T	7	5.53	0.61	0.82
S x T	21	162.14	0.61	1.60
Y x S x T	21	6.53	0.25	0.84
Error (b)	168	104.87	0.91	68.66

* Significant at 5% level
** Significant at 1% level

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Table : 4.1 Effect of spacing and fertility levels on plant height (cm)

Treatments	Plant height		
	2001	2002	Pooled mean
Spacing			
S_1 (30 x 10 cm)	50.96	50.97	50.97
S_2 (30 x 15 cm)	51.07	50.77	50.92
S_3 (45 x 10 cm)	51.13	51.18	51.15
S_4 (45 x 15 cm)	51.05	51.09	51.07
Sem$\pm$	0.945	0.915	0.658
CD at 5%	NS	NS	NS
Fertility levels			
T_1 (control)	38.46	38.38	38.42
T_2 (75% recommended dose of NPK)	52.26	52.31	52.29
T_3 (100% recommended dose of NPK)	52.95	52.97	52.96
T_4 (125 % recommended dose of NPK)	52.80	52.83	52.82
T_5 (vermicompost 2.5 t ha^{-1})	52.47	52.47	52.47
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	53.10	52.88	52.99
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	53.23	53.00	53.11
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	53.15	53.18	53.16
Sem$\pm$	0.907	0.941	0.654
CD at 5%	2.549	2.644	1.832

NS = non- significant

Table : 4.2 Effect of spacing and fertility levels on number of leaves per plant at harvest.

Treatments	No. of leaves per plant at harvest		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	9.92	9.97	9.95
S_2 (30 x 15 cm)	9.98	10.02	10.00
S_3 (45 x 10 cm)	10.53	10.59	10.56
S_4 (45 x 15 cm)	10.58	10.64	10.61
SEm$\pm$	0.172	0.169	0.121
CD at 5%	0.551	0.541	0.359
Fertility levels			
T_1 (control)	6.60	6.62	6.61
T_2 (75% recommended dose of NPK)	9.77	9.84	9.80
T_3 (100% recommended dose of NPK)	10.62	10.73	10.67
T_4 (125 % recommended dose of NPK)	10.35	10.37	10.36
T_5 (vermicompost 2.5 t ha^{-1})	10.05	10.10	10.08
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	11.14	11.20	11.17
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	11.88	11.94	11.91
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	11.61	11.66	11.63
SEm$\pm$	0.172	0.169	0.121
CD at 5%	0.482	0.477	0.338

Table : 4.3 Effect of spacing and fertility levels on fresh weight of leaves at harvest (g).

Treatments	Fresh weight of leaves at harvest		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	45.20	45.59	45.40
S_2 (30 x 15 cm)	48.27	48.66	48.47
S_3 (45 x 10 cm)	52.70	52.68	52.69
S_4 (45 x 15 cm)	49.60	48.70	49.16
SEm$\pm$	0.566	0.530	0.388
CD at 5%	1.812	1.697	1.153
Fertility levels			
T_1 (control)	32.73	32.58	32.68
T_2 (75% recommended dose of NPK)	46.37	46.26	48.32
T_3 (100% recommended dose of NPK)	51.26	51.13	51.19
T_4 (125 % recommended dose of NPK)	48.78	48.77	48.77
T_5 (vermicompost 2.5 t ha^{-1})	47.96	47.84	47.90
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	52.49	52.53	52.51
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	56.83	57.00	56.92
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	55.12	55.14	55.13
SEm$\pm$	0.623	0.587	0.428
CD at 5%	1.750	1.649	1.199

Table : 4.4 Effect of spacing and fertility levels on dry weight of leaves at harvest (g).

Treatments	Dry weight of leaves at harvest		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	5.65	5.70	5.67
S_2 (30 x 15 cm)	5.68	5.73	5.70
S_3 (45 x 10 cm)	6.02	6.02	6.02
S_4 (45 x 15 cm)	5.98	5.87	5.92
SEm$\pm$	0.095	0.073	0.060
CD at 5%	0.305	0.235	0.179
Fertility levels			
T_1 (control)	3.90	3.88	3.89
T_2 (75% recommended dose of NPK)	5.53	5.51	5.52
T_3 (100% recommended dose of NPK)	6.11	6.09	6.10
T_4 (125 % recommended dose of NPK)	5.81	5.81	5.81
T_5 (vermicompost 2.5 t ha^{-1})	5.72	5.70	5.71
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.26	6.26	6.26
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.77	6.79	6.78
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.57	6.57	6.57
SEm$\pm$	0.091	0.096	0.066
CD at 5%	0.256	0.271	0.186

Table : 4. 5 Effect of spacing and fertility levels on neck thickness of onion (cm).

Treatments	Neck thickness		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	0.82	0.83	0.82
S_2 (30 x 15 cm)	0.85	0.87	0.86
S_3 (45 x 10 cm)	0.87	0.90	0.89
S_4 (45 x 15 cm)	0.89	0.92	0.91
SEm$\pm$	0.010	0.011	0.08
CD at 5%	0.035	0.036	0.023
Fertility levels			
T_1 (control)	0.62	0.62	0.62
T_2 (75% recommended dose of NPK)	0.66	0.68	0.67
T_3 (100% recommended dose of NPK)	0.71	0.73	0.72
T_4 (125 % recommended dose of NPK)	0.79	0.82	0.81
T_5 (vermicompost 2.5 t ha^{-1})	0.88	0.97	0.93
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	1.02	1.03	1.02
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	1.06	1.08	1.07
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	1.10	1.12	1.11
SEm$\pm$	0.015	0.016	0.011
CD at 5%	0.041	0.044	0.030

Table : 4.6 Effect of spacing and fertility levels on neck length (cm) of onion.

Treatments	**Neck length**		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	5.85	5.90	5.87
S_2 (30 x 15 cm)	6.02	6.05	6.04
S_3 (45 x 10 cm)	6.16	6.17	6.16
S_4 (45 x 15 cm)	6.30	6.32	6.31
SEm$\pm$	0.091	0.086	0.062
CD at 5%	0.292	0.272	0.185
Fertility levels			
T_1 (control)	5.70	5.76	5.73
T_2 (75% recommended dose of NPK)	5.80	5.83	5.81
T_3 (100% recommended dose of NPK)	5.94	5.94	5.94
T_4 (125 % recommended dose of NPK)	6.07	6.09	6.08
T_5 (vermicompost 2.5 t ha^{-1})	6.19	6.22	6.21
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.27	6.30	6.28
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.31	6.33	6.32
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.38	6.41	6.40
SEm$\pm$	0.093	0.096	0.067
CD at 5%	0.260	0.271	0.187

Table : 4.7a Effect of spacing and fertility levels on equatorial diameter (cm) of onion.

Treatments	Equatorial diameter		
	2001	2002	Pooled mean
Spacing			
S_1 (30 x 10 cm)	4.91	4.94	4.92
S_2 (30 x 15 cm)	5.17	5.20	5.18
S_3 (45 x 10 cm)	5.23	5.26	5.24
S_4 (45 x 15 cm)	5.26	5.31	5.28
SEm±	0.055	0.060	0.041
CD at 5%	0.177	0.192	0.121
Fertility levels			
T_1 (control)	4.03	4.11	4.07
T_2 (75% recommended dose of NPK)	4.79	4.81	4.80
T_3 (100% recommended dose of NPK)	5.33	5.36	5.34
T_4 (125 % recommended dose of NPK)	5.24	5.27	5.25
T_5 (vermicompost 2.5 t ha^{-1})	5.13	5.17	5.15
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	5.41	5.45	5.43
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	5.62	5.63	5.62
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	5.57	5.63	5.60
SEm±	0.074	0.079	0.054
CD at 5%	0.209	0.223	0.153

Table : 4.8 Effect of spacing and fertility levels on polar diameter (cm) of onion.

Treatments	Polar diameter		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	4.62	4.66	4.64
S_2 (30 x 15 cm)	4.62	4.66	4.64
S_3 (45 x 10 cm)	4.82	4.87	4.84
S_4 (45 x 15 cm)	4.78	4.84	4.81
SEm±	0.052	0.057	0.038
CD at 5%	0.165	0.182	0.114
Fertility levels			
T_1 (control)	3.57	3.62	3.59
T_2 (75% recommended dose of NPK)	4.62	4.68	4.65
T_3 (100% recommended dose of NPK)	4.81	4.85	4.83
T_4 (125 % recommended dose of NPK)	4.72	4.76	4.74
T_5 (vermicompost 2.5 t ha^{-1})	4.67	4.72	4.69
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	4.95	4.99	4.97
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	5.24	5.27	5.25
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	5.12	5.19	5.15
SEm±	0.069	0.076	0.051
CD at 5%	0.193	0.213	0.143

Table : 4.9 Effect of spacing and fertility levels on number of scales per bulb of onion.

Treatments	No. of scales/ bulb		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	6.21	6.26	6.23
S_2 (30 x 15 cm)	6.12	6.28	6.20
S_3 (45 x 10 cm)	6.40	6.52	6.46
S_4 (45 x 15 cm)	6.27	6.42	6.35
SEm$\pm$	0.061	0.059	0.043
CD at 5%	0.194	0.192	0.127
Fertility levels			
T_1 (control)	4.71	4.78	4.74
T_2 (75% recommended dose of NPK)	5.81	5.89	5.85
T_3 (100% recommended dose of NPK)	6.53	6.62	6.57
T_4 (125 % recommended dose of NPK)	6.20	6.32	6.26
T_5 (vermicompost 2.5 t ha^{-1})	6.10	6.19	6.14
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.74	6.84	6.79
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	7.13	7.22	7.17
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	6.80	7.10	6.95
SEm$\pm$	0.082	0.082	0.058
CD at 5%	0.230	0.232	0.163

Table : 4.10 Effect of spacing and fertility levels on thickness of scales (cm) of onion.

Treatments	Thickness of scales		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	0.229	0.233	0.231
S_2 (30 x 15 cm)	0.241	0.244	0.242
S_3 (45 x 10 cm)	0.233	0.238	0.235
S_4 (45 x 15 cm)	0.242	0.246	0.244
SEm$\pm$	0.0028	0.0029	0.0020
CD at 5%	0.0089	0.0091	0.0059
Fertility levels			
T_1 (control)	0.187	0.189	0.188
T_2 (75% recommended dose of NPK)	0.211	0.213	0.212
T_3 (100% recommended dose of NPK)	0.247	0.250	0.248
T_4 (125 % recommended dose of NPK)	0.227	0.231	0.229
T_5 (vermicompost 2.5 t ha^{-1})	0.219	0.223	0.221
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.261	0.266	0.263
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.271	0.277	0.274
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.269	0.275	0.272
SEm$\pm$	0.0035	0.0031	0.0024
CD at 5%	0.0099	0.0089	0.0066

Table : 4.11a Effect of spacing and fertility levels on fresh weight of bulb (g).

Treatments	Fresh weight of bulb		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	77.08	77.75	77.41
S_2 (30 x 15 cm)	77.77	77.87	77.82
S_3 (45 x 10 cm)	79.46	78.73	79.09
S_4 (45 x 15 cm)	80.12	80.52	80.32
SEm±	0.631	0.644	0.451
CD at 5%	2.017	2.062	1.340
Fertility levels			
T_1 (control)	56.36	56.82	56.59
T_2 (75% recommended dose of NPK)	68.99	69.54	69.27
T_3 (100% recommended dose of NPK)	79.17	79.90	79.53
T_4 (125 % recommended dose of NPK)	76.20	76.58	76.39
T_5 (vermicompost 2.5 t ha^{-1})	70.88	71.33	71.11
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	86.25	86.71	86.48
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	97.03	92.54	94.78
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	93.97	96.31	95.14
SEm±	0.598	0.642	0.439
CD at 5%	1.681	1.805	1.230

Table : 4.12 Effect of spacing and fertility levels on volume of bulb (cc) of onion.

Treatments	**Volume of bulb**		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	49.63	49.67	49.65
S_2 (30 x 15 cm)	51.05	51.16	51.10
S_3 (45 x 10 cm)	52.93	53.04	52.98
S_4 (45 x 15 cm)	53.04	53.15	53.09
SEm$\pm$	0.742	0.755	0.529
CD at 5%	2.373	2.415	1.572
Fertility levels			
T_1 (control)	41.67	41.59	41.63
T_2 (75% recommended dose of NPK)	47.95	48.16	48.05
T_3 (100% recommended dose of NPK)	53.70	53.78	53.74
T_4 (125 % recommended dose of NPK)	53.46	53.54	53.50
T_5 (vermicompost 2.5 t ha^{-1})	51.12	51.25	51.18
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	54.32	54.42	54.37
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	55.98	56.08	56.03
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	55.08	55.22	55.15
SEm$\pm$	0.913	0.963	0.664
CD at 5%	2.566	2.706	1.860

Table : 4.13a Effect of spacing and fertility levels on bulb yield (q ha^{-1}) of onion.

Treatments	Bulb yield		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	257.18	258.75	257.96
S_2 (30 x 15 cm)	172.92	173.03	172.97
S_3 (45 x 10 cm)	174.34	174.95	174.64
S_4 (45 x 15 cm)	115.50	115.80	115.65
SEm$\pm$	3.574	3.624	2.545
CD at 5%	11.434	11.594	7.562
Fertility levels			
T_1 (control)	128.53	129.00	128.76
T_2 (75% recommended dose of NPK)	158.30	158.72	158.51
T_3 (100% recommended dose of NPK)	181.62	182.44	182.03
T_4 (125 % recommended dose of NPK)	175.12	174.82	174.97
T_5 (vermicompost 2.5 t ha^{-1})	159.73	162.80	161.27
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	197.97	198.24	198.10
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	224.16	224.43	224.29
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	214.47	214.61	214.54
SEm$\pm$	3.658	3.709	2.605
CD at 5%	10.279	10.422	7.301

Table : 4.14 Effect of spacing and fertility levels on T.S.S. (%) of onion.

Treatments	TSS		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	12.16	12.19	12.18
S_2 (30 x 15 cm)	12.18	12.22	12.20
S_3 (45 x 10 cm)	12.20	12.23	12.22
S_4 (45 x 15 cm)	12.21	12.24	12.23
SEm$\pm$	0.128	0.103	0.082
CD at 5%	NS	NS	NS
Fertility levels			
T_1 (control)	12.03	12.05	12.04
T_2 (75% recommended dose of NPK)	12.08	12.10	12.09
T_3 (100% recommended dose of NPK)	12.13	12.17	12.15
T_4 (125 % recommended dose of NPK)	12.18	12.23	12.20
T_5 (vermicompost 2.5 t ha^{-1})	12.20	12.24	12.22
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	12.26	12.28	12.27
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	12.31	12.34	12.32
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	12.34	12.37	12.36
SEm$\pm$	0.114	0.121	0.083
CD at 5%	0.319	0.339	0.232

N.S.=Non-significant

Table : 4.15 Effect of spacing and fertility levels on sulphur content (%) in onion.

Treatments	Sulphur content		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	0.665	0.668	0.666
S_2 (30 x 15 cm)	0.667	0.671	0.669
S_3 (45 x 10 cm)	0.675	0.678	0.677
S_4 (45 x 15 cm)	0.674	0.676	0.675
SEm$\pm$	0.006	0.005	0.004
CD at 5%	NS	NS	NS
Fertility levels			
T_1 (control)	0.636	0.638	0.637
T_2 (75% recommended dose of NPK)	0.657	0.660	0.658
T_3 (100% recommended dose of NPK)	0.676	0.679	0.678
T_4 (125 % recommended dose of NPK)	0.670	0.673	0.672
T_5 (vermicompost 2.5 t ha^{-1})	0.663	0.668	0.666
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.683	0.686	0.684
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.690	0.693	0.692
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.686	0.690	0.688
SEm$\pm$	0.006	0.006	0.004
CD at 5%	0.017	0.016	0.011

N.S=Non-significant

Table : 4.16 Effect of spacing and fertility levels on pungency (Allyl - propyl --disulphide) of onion.

Treatments	Pungency (allyl propyl disulphide)		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	6.80	6.84	6.82
S_2 (30 x 15 cm)	6.84	6.88	6.86
S_3 (45 x 10 cm)	6.92	6.97	6.94
S_4 (45 x 15 cm)	6.87	6.91	6.89
SEm$\pm$	0.091	0.085	0.062
CD at 5%	NS	NS	NS
Fertility levels	6.54	6.60	6.57
T_1 (control)	6.65	6.70	6.67
T_2 (75% recommended dose of NPK)	6.94	6.97	6.95
T_3 (100% recommended dose of NPK)	6.79	6.83	6.81
T_4 (125 % recommended dose of NPK)	6.72	6.77	6.74
T_5 (vermicompost 2.5 t ha^{-1})	6.99	7.02	7.01
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	7.21	7.25	7.23
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	7.05	7.08	7.07
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.093	0.096	0.067
SEm$\pm$	0.260	0.271	0.187
CD at 5%			

N.S.= Non-significant

Table : 4.17 Effect of spacing and fertility levels on vitamin 'C' content (mg/100 g of pulp) in onion.

Treatments	**Vitamin 'C' content**		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	9.40	9.44	9.42
S_2 (30 x 15 cm)	9.46	9.48	9.46
S_3 (45 x 10 cm)	9.51	9.54	9.53
S_4 (45 x 15 cm)	9.46	9.48	9.47
SEm$\pm$	0.099	0.096	0.069
CD at 5%	NS	NS	NS
Fertility levels			
T_1 (control)	9.19	9.22	9.20
T_2 (75% recommended dose of NPK)	9.22	9.25	9.23
T_3 (100% recommended dose of NPK)	9.57	9.60	9.58
T_4 (125 % recommended dose of NPK)	9.42	9.45	9.44
T_5 (vermicompost 2.5 t ha^{-1})	9.35	9.37	9.36
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	9.60	9.64	9.62
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	9.65	9.67	9.66
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	9.66	9.70	9.68
SEm$\pm$	0.096	0.094	0.067
CD at 5%	0.269	0.264	0.188

NS = non- significant

Table : 4.18 Effect of spacing and fertility levels on N content (%) in bulb of onion.

Treatments	N content		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	0.757	0.764	0.760
S_2 (30 x 15 cm)	0.766	0.771	0.768
S_3 (45 x 10 cm)	0.784	0.789	0.786
S_4 (45 x 15 cm)	0.774	0.780	0.777
SEm$\pm$	0.0054	0.0054	0.0038
CD at 5%	0.0171	0.0171	0.0113
Fertility levels			
T_1 (control)	0.537	0.540	0.539
T_2 (75% recommended dose of NPK)	0.752	0.755	0.754
T_3 (100% recommended dose of NPK)	0.799	0.804	0.801
T_4 (125 % recommended dose of NPK)	0.790	0.798	0.794
T_5 (vermicompost 2.5 t ha^{-1})	0.783	0.788	0.785
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.810	0.818	0.814
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.842	0.850	0.846
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.850	0.855	0.853
SEm$\pm$	0.0061	0.0056	0.0041
CD at 5%	0.0170	0.0157	0.0115

Table : 4.19a Effect of spacing and fertility levels on phosphorus content (%) of onion.

Treatments	P content		
	2001	2002	Pooled mean
Spacing			
S_1 (30 x 10 cm)	0.330	0.348	0.339
S_2 (30 x 15 cm)	0.336	0.350	0.343
S_3 (45 x 10 cm)	0.348	0.366	0.357
S_4 (45 x 15 cm)	0.344	0.357	0.351
SEm$\pm$	0.0035	0.0037	0.0025
CD at 5%	0.0112	0.0118	0.0075
Fertility levels			
T_1 (control)	0.260	0.265	0.263
T_2 (75% recommended dose of NPK)	0.278	0.283	0.280
T_3 (100% recommended dose of NPK)	0.330	0.355	0.343
T_4 (125 % recommended dose of NPK)	0.305	0.325	0.315
T_5 (vermicompost 2.5 t ha^{-1})	0.290	0.300	0.295
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.365	0.395	0.380
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.470	0.478	0.474
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	0.418	0.443	0.430
SEm$\pm$	0.0045	0.0045	0.0032
CD at 5%	0.0127	0.0127	0.0090

Table : 4.20 Effect of spacing and fertility levels on potassium content (%) of onion.

Treatments	Potassium content		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	1.09	1.09	1.09
S_2 (30 x 15 cm)	1.09	1.10	1.09
S_3 (45 x 10 cm)	1.12	1.12	1.12
S_4 (45 x 15 cm)	1.11	1.12	1.12
SEm$\pm$	0.0086	0.0081	0.0059
CD at 5%	0.0274	0.0258	0.0175
Fertility levels			
T_1 (control)	1.08	1.09	1.08
T_2 (75% recommended dose of NPK)	1.09	1.09	1.09
T_3 (100% recommended dose of NPK)	1.12	1.12	1.12
T_4 (125 % recommended dose of NPK)	1.10	1.10	1.10
T_5 (vermicompost 2.5 t ha^{-1})	1.09	1.10	1.09
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	1.11	1.12	1.12
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	1.12	1.13	1.12
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	1.12	1.12	1.12
SEm$\pm$	0.0084	0.0077	0.0057
CD at 5%	0.0236	0.0216	0.0160

Table : 4.22a Effect of spacing and fertility levels on P uptake(kg/ha) of onion.

Treatments	P uptake		
	2001	2002	Pooled mean
Spacing			
S_1 (30 x 10 cm)	87.38	92.54	89.96
S_2 (30 x 15 cm)	59.91	62.54	61.23
S_3 (45 x 10 cm)	62.57	66.08	64.33
S_4 (45 x 15 cm)	40.75	42.59	41.67
SEm$\pm$	1.782	1.884	1.297
CD at 5%	5.700	6.026	3.852
Fertility levels			
T_1 (control)	33.15	34.04	33.59
T_2 (75% recommended dose of NPK)	44.01	45.10	44.55
T_3 (100% recommended dose of NPK)	59.60	64.26	61.93
T_4 (125 % recommended dose of NPK)	53.24	56.80	55.02
T_5 (vermicompost 2.5 t ha^{-1})	46.32	48.79	47.56
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	81.75	87.02	84.39
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	105.32	107.14	106.23
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	77.85	84.34	81.09
SEm$\pm$	1.483	1.534	1.067

CD at 5%	4.167	4.311	2.99

Table : 4. 23 Effect of spacing and fertility levels on K uptake(kg/ha) of onion.

Treatments	K uptake		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	279.54	282.03	280.78
S_2 (30 x 15 cm)	189.59	190.04	189.81
S_3 (45 x 10 cm)	196.42	197.51	196.97
S_4 (45 x 15 cm)	129.05	129.64	129.34
SEm±	5.478	5.494	3.879
CD at 5%	17.525	17.059	11.525
Fertility levels			
T_1 (control)	138.69	139.60	139.14
T_2 (75% recommended dose of NPK)	171.76	172.67	172.21
T_3 (100% recommended dose of NPK)	201.73	203.08	202.41
T_4 (125 % recommended dose of NPK)	191.86	191.95	191.90
T_5 (vermicompost 2.5 t ha^{-1})	174.26	178.14	176.20
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	220.08	221.04	220.56
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	251.56	252.55	252.05
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	239.26	239.40	239.33
SEm±	4.715	4.647	3.310

CD at 5%	13.250	13.059	9.279

Table : 4.24 Effect of spacing and fertility levels on available N (kg/ha) in soil after harvesting.

Treatments	Available N(kg/ha)		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	126.98	127.34	127.16
S_2 (30 x 15 cm)	127.81	127.97	127.89
S_3 (45 x 10 cm)	138.02	139.45	138.74
S_4 (45 x 15 cm)	132.08	132.15	132.11
SEm$\pm$	2.153	2.355	1.595
CD at 5%	6.886	7.533	4.739
Fertility levels			
T_1 (control)	101.47	104.02	102.74
T_2 (75% recommended dose of NPK)	126.36	128.43	126.39
T_3 (100% recommended dose of NPK)	135.52	135.70	135.61
T_4 (125 % recommended dose of NPK)	135.48	135.83	135.65
T_5 (vermicompost 2.5 t ha^{-1})	133.25	133.38	133.31
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	137.57	137.68	137.62
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	140.57	140.94	140.76
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	139.54	139.85	139.70
SEm$\pm$	2.153	2.677	1.810

CD at 5%	6.886	7.522	5.074

Table : 4.25 Effect of spacing and fertility levels on available P_2O_5 (kg/ha) in soil after harvesting.

Treatments	Available P_2O_5		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	15.93	15.94	15.93
S_2 (30 x 15 cm)	16.61	16.66	16.64
S_3 (45 x 10 cm)	16.84	16.63	16.74
S_4 (45 x 15 cm)	16.77	16.82	16.79
SEm$\pm$	0.188	0.177	0.129
CD at 5%	0.601	0.566	0.383
Fertility levels			
T_1 (control)	14.23	14.28	14.26
T_2 (75% recommended dose of NPK)	15.32	15.36	15.34
T_3 (100% recommended dose of NPK)	16.89	16.95	16.92
T_4 (125 % recommended dose of NPK)	16.34	16.40	16.37
T_5 (vermicompost 2.5 t ha^{-1})	15.90	15.99	15.95
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	16.90	17.02	16.96
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	18.75	18.04	18.39
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	17.99	18.05	18.02

SEm±	0.243	0.235	0.169
CD at 5%	0.683	0.661	0.474

Table : 4.26 Effect of spacing and fertility levels on available K_2O (kg/ha) in soil after harvesting.

Treatments	Available K_2O		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	129.16	130.06	129.61
S_2 (30 x 15 cm)	133.56	134.56	130.06
S_3 (45 x 10 cm)	133.73	135.50	134.61
S_4 (45 x 15 cm)	138.60	138.60	138.60
SEm±	1.857	1.642	1.239
CD at 5%	5.939	5.254	3.682
Fertility levels			
T_1 (control)	110.31	111.25	110.78
T_2 (75% recommended dose of NPK)	130.65	131.65	131.15
T_3 (100% recommended dose of NPK)	138.61	139.39	139.00
T_4 (125 % recommended dose of NPK)	135.95	137.57	136.76
T_5 (vermicompost 2.5 t ha^{-1})	134.78	135.78	135.28
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	138.70	139.30	139.00
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	140.96	141.67	141.32
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	140.13	140.83	140.48

SEm±	2.307	1.806	1.465
CD at 5%	6.482	5.074	4.106

Table : 4.21a Effect of spacing and fertility levels on nitrogen (kg/ha) uptake in onion bulb.

Treatments	**Nitrogen uptake**		
	2001	**2002**	**Pooled mean**
Spacing			
S_1 (30 x 10 cm)	197.77	200.82	199.30
S_2 (30 x 15 cm)	134.59	135.56	135.08
S_3 (45 x 10 cm)	139.22	140.48	139.85
S_4 (45 x 15 cm)	91.00	91.89	91.45
SEm±	3.472	3.522	2.473
CD at 5%	11.109	11.268	7.348
Fertility levels			
T_1 (control)	68.82	69.58	69.20
T_2 (75% recommended dose of NPK)	118.95	119.78	119.37
T_3 (100% recommended dose of NPK)	144.93	146.40	145.66
T_4 (125 % recommended dose of NPK)	138.18	139.26	138.72
T_5 (vermicompost 2.5 t ha^{-1})	124.68	128.00	126.34
T_6 (25% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	160.17	161.80	160.99
T_7 (50% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	187.67	189.59	168.63
T_8 (75% recommended dose of NPK + vermicompost 2.5 t ha^{-1})	181.75	183.09	182.42
SEm±	3.042	3.094	2.169
CD at 5%	8.549	8.695	6.081

Table 4.28 Comparative economics of various treatments

Treatment combinations	Yield (q ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Treatment cost (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
S_1T_1	184.03	20600	5800	26400	101217	74817	2.83:1
S_1T_2	227.91	20600	7500	28130	125351	97221	3.45:1
S_1T_3	260.53	20600	8105	28705	143291	114586	3.99:1
S_1T_4	250.46	20600	8683	29283	137753	108470	3.70:1
S_1T_5	228.88	20600	10800	31400	125884	94484	3.00:1
S_1T_6	284.20	20600	11342	31942	156310	124368	3.89:1
S_1T_7	323.96	20600	11953	32553	178178	145625	4.47:1
S_1T_8	303.75	20600	12530	33130	167063	133933	4.04:1
S_2T_1	123.85	20600	5300	25900	68118	42218	1.63:1
S_2T_2	153.18	20600	7030	27630	107226	79596	2.88:1
S_2T_3	173.76	20600	7605	28205	121632	93424	3.31:1
S_2T_4	168.07	20600	8183	28783	117649	88866	3.08:1
S_2T_5	155.62	20600	10300	30900	108934	78034	2.52:1
S_2T_6	189.40	20600	10842	31442	132580	101138	3.21:1
S_2T_7	215.93	20600	11453	32053	151151	119098	3.71:1
S_2T_8	204.00	20600	12030	32630	142800	110170	3.37:1
S_3T_1	124.55	20600	5300	25900	68503	42603	1.64:1
S_3T_2	152.04	20600	7030	27630	106428	78798	2.85:1
S_3T_3	177.02	20600	7605	28205	150467	122262	4.33:1
S_3T_4	168.22	20600	8183	28783	142987	114204	3.96:1
S_3T_5	156.64	20600	10300	30900	133144	102244	3.30:1
S_3T_6	191.73	20600	10842	31442	162971	131528	4.18:1
S_3T_7	220.91	20600	11453	32052	187774	155721	4.85:1
S_3T_8	205.06	20600	12030	32630	174301	141671	4.34:1
S_4T_1	82.62	20600	4755	25355	57834	32479	1.28:1
S_4T_2	100.91	20600	6485	27085	70637	43552	1.60:1
S_4T_3	116.82	20600	7060	27660	99297	71637	2.58:1
S_4T_4	112.12	20600	7638	28238	78484	50246	1.77:1
S_4T_5	103.93	20600	9755	30355	88341	97986	1.91:1
S_4T_6	127.10	20600	10297	30897	108035	77138	2.49:1
S_4T_7	136.39	20600	10908	31508	115932	84424	2.67:1
S_4T_8	145.36	20600	11485	32085	123556	91471	2.85:1