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Influence of integrated nutrient management on yield, quality and economics of cumin (*Cuminum cyminum*) production under semi-arid conditions

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ABSTRACT

The continuous use of high levels of chemical fertilizers is adversely affecting the sustainability of agricultural production and causing environmental pollution. Therefore, we must find ways to reduce the use of chemical fertilizers. The use of organic fertilizers is one of the solutions for sustainable fertility and productivity. The objective of this study was to investigate the effect of integrated nutrient management on growth, productivity, quality and economics of cumin (*Cuminum cyminum* L.). A field experiment was conducted continuously for 3 winter (*rabi*) seasons stating from 2007 to 2010 at Jobner, Rajasthan. The experiment consisted of 14 treatments for application of recommended dose of fertilizer (RDF) to cumin, i.e. 30 kg/ha, through different sources, viz. control, fertilizers or organic [farmyard manure (FYM), poultry manure (PM), vermicompost (VC) and neem cake (NC)] alone or in combinations, was laid out in randomized block design with 3 replications. Based on three years of study the results revealed that in cumin nutrient management through organic sources, fertilizer sources alone or in combination have significant effect on growth, yield attributes, yield, economics, volatile oil content and soil fertility status. The integrated application of 50% RDF through VC + 50% RDF through fertilizers gave higher values of all the growth and yield attributes, viz. plant height, branches/plant, umbels/plant, umbellates/umbel, seeds/umbellate and test weight to the magnitude of 14.7, 20.9, 34.8, 23.7, 40.7 and 11.3% over absolute control, respectively, closely followed by 100% RDF through fertilizers. Among the different nutrient management practices, significantly highest mean values were recorded for seed yield (474 kg/ha), straw yield (1221 kg/ha), biological yield (1695 kg/ha), gross monetary returns (₹ 75840/ha), net monetary returns (₹ 57861/ha), benefit:cost ratio (3.22) and volatile oil content (3.26%) in treatment with 50% RDF through VC + 50% RDF through fertilizers realizing 75.6, 46.8, 53.8, 75.6, 111.2, 8.6 and 7.9% increase over absolute control, respectively. The significantly highest value of organic carbon (0.28%) was recorded with 100% RDF through FYM, whereas 75% RDF through VC + 25% RDF through fertilizers indicated highest available nitrogen balance (146.5 kg/ha) followed with 50% RDF through VC + 50% RDF through fertilizers (145.3 kg/ha). Therefore, in cumin it can be recommended to apply 50% RDF through VC + 50% RDF through fertilizers, which will reduce the load of chemical fertilizers up to 50%.

Key words: Cumin, Farmyard manure, Integrated nutrient management, Neem cake, Poultry manure, Vermicompost

India has been recognized as a land of spices and at present it is the world's largest producer, consumer and exporter of seed spices. Among seed spices, cumin (*Cuminum cyminum* L.) is an important commercial crop of arid and semi-arid regions of India belonging to the umbellifereae family, is valued for its aroma, medicinal and therapeutic properties. In India, it is mainly cultivated in Rajasthan, Gujarat, Karnataka and Odisha. There is a lot of potential for cumin crop in our country because of the very high export potential and daily internal consumption as it finds place in almost all the Indian dishes. Crushed cumin seeds are used as a condiment in a variety of dishes. Cumin seeds contain volatile oil (2–5%) that imparts the characteristic aroma to the seeds. The oil is used in perfumery and for flavouring liquors and cordials. In indigenous medicine, cumin seeds have long been considered as a stimulant,

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carminative and are used for therapeutic purposes. They are also used in veterinary medicines. They are essential ingredient in mixed soups, sausages, pickles, cheese and meat dishes, and also used for seasoning breads, cakes and candies. The present productivity of the crop in the country is below the potential due to variety of reasons including nutrient management.

The continuous use of high levels of chemical fertilizers is adversely affecting the sustainability of agricultural production and causing environmental pollution (Virmani 1994). In coming decades, a major issue in designing sustainable agricultural system will be the management of soil organic matter and the rational use of organic inputs. Inadequate and imbalanced application of nutrients is one of major factors for low yield and poor quality. Exclusive application of fertilizer creates deleterious effect on soil fertility due to limitation of one or more nutrients including micronutrients and poor soil health leading to decline in productivity. No single source of nutrient is capable of supplying plant nutrients in adequate amount and balanced proportion. For realizing the inherited yield potentials of high yielding varieties, supplement must be given through the application of manures and fertilizers. In recent years, there has been increasing recognition of the importance of organics as the global consumers are showing inclination towards health cautiousness with their day-to-day diet. Crops grown using organic inputs having less or no chemicals are being preferred over conventionally produced food by the end users, especially medicinally useful crops. Food material produced organically has got its place in food market in both developed and developing countries. Recently, there has been increasing importance of organic sources of plant nutrients due to growing ecological concern and depleting inherent soil fertility leading to multiple deficiencies of essential plant nutrients. The results of long-term fertilizer experiments have emphasized that sustainability can only be maintained by integration of fertilizers and organic sources of nutrients (Chettri and Bandhopadhya 2005). However, organic manures cannot meet the total nutrient needs of modern agriculture, integrated use of nutrients from fertilizers and organic resources seems to be imperative. The basic concept underlying the integrated nutrient management system (INM), nevertheless, can act for better maintenance and can also possibly improve soil fertility for achieving sustainable crop productivity on long-term basis and will also reduce fertilizer input cost. The different components of integrated nutrient management possess great diversity in terms of chemical and physical properties and nutrient release patterns. Addition of organic manures like farmyard manure, vermicompost, neem cake, poultry manure, etc. not only supplies most of the essential plant nutrients, but also improves the soil structure by providing binding substance to soil aggregates leading to increase in cation exchange capacity and water holding capacity of the soil. Besides this, the organic manures improve the efficiencies of applied fertilizers. Furthermore, the decomposition and mineralization of organic manure is a slow process, which could match the nutrient requirement of a crop and thus limits the loss of precious plant food. Organic manures produce food of high quality, encourage and enhance biological cycles within the farming system involving microorganisms, soil flora and fauna, plants and animals and maintain and increase the long-term fertility of soils (Mahapatra *et al.* 2009). Hence, the replacement of external inputs, viz. chemical fertilizer by farm-derived organic inputs normally leads to a reduction in variable input costs under organic management. By virtue of using less quantity of chemical fertilizers and dependency upon naturally available sources of nutrients, organic food could provide better vistas towards high remuneration with premium price in market with inherent lesser cost advantage. Traditionally nutrient management in cumin is being done by application of chemical fertilizers. However, meagre information is available on the combined effect of organic and inorganic source of nutrition on cumin. Therefore, an attempt was made to evaluate different organic and inorganic sources of nutrition for realizing higher yield, quality and profitability in cumin.

MATERIALS AND METHODS

The present field investigation was carried out continuously for 3 winter (*rabi*) season starting from 2007 to 2010 at SKN College of Agriculture, Jobner, Jaipur (Rajasthan) situated at latitude of $26^0$05’ N, longitude of $75^0$20’E and at an altitude of 427 m above mean sea level. The soil was loamy sand, low in organic carbon (0.20%), available N (125.9 kg/ha), available P (7.4 kg/ha) and medium in available K (148.6 kg/ha) with alkaline (pH 8.3) in reaction having 1.54 Mg/m^3 bulk density, 2.65 Mg/m^3 particle density, 13.25% field capacity and 4.89% permanent wilting point at the beginning of the experiment. The experiment was laid out in randomized block design with three replications for three years. The experiment comprised of fourteen treatments for application of recommended dose of fertilizer (RDF) to cumin through different sources *viz.* control, 100% RDF though fertilizers (30 kg N + 20 kg P_2O_5 + 0 kg K_2O/ha), 100% RDF through farmyard manure (FYM), 100% RDF through poultry manure (PM), 100% RDF through vermicompost (VC), 100% RDF through neem cake (NC), 50% RDF through FYM + 50% RDF through fertilizers, 50% RDF through PM + 50% RDF through fertilizers, 50% RDF through VC + 50% RDF through fertilizers, 50% RDF through NC + 50% RDF through fertilizers, 75% RDF through FYM + 25% RDF through fertilizers, 75% RDF through PM + 25% RDF through fertilizers, 75% RDF through VC + 25% RDF through fertilizers and 75% RDF through NC + 25% RDF through fertilizers. Full dose of N and P as per treatments were applied manually through DAP and urea at the time of sowing. Nitrogen content was estimated in organic sources on dry-weight basis and their quantities required for a specific amount of N as per treatment were calculated. The well decomposed FYM, PM, VC and NC with mean composition (N 0.43, 2.80, 1.54 and 4.80%, P 0.24, 2.23, 1.24 and 1.07% and K 0.51, 1.43, 0.85 and 1.28%, respectively) were applied two weeks before sowing and incorporated in soil as per treatments. RZ 209 cumin variety was sown in rows 30 cm apart using 14 kg seed/ha in the first week of November during all the years. All improved package of practices were followed to raise the crop under irrigated conditions. Data on growth and yield attributes were taken from five tagged plants. Biological and economic yields were taken from net plot. Straw yield was obtained by subtracting seed yield from the total biological yield. To ascertain the economic feasibility of different treatments, economics of treatments was worked out on the basis of prevailing market prices of inputs and outputs and expressed in terms of net profit per hectare so that most remunerative treatment could be recommended. The volatile oil was estimated by using Clevenger's apparatus (AOAC 1988). The composite soil sample was analyzed after harvesting of the crop to find out the change in organic carbon and available nitrogen. Regular analysis of variance was performed for each trait for all three seasons and the combined (Pooled) analysis over seasons after testing error variance homogeneity was carried out according to the procedure outlined by Gomez and Gomez (1984), using the MSTATC version 2.1 (Michigan State University, USA) statistical package design. Significant differences between the treatments were compared with the critical difference at ± 5% probability by LSD.

RESULTS AND DISCUSSION

Growth and yield attributes

The nutrient management through organic sources and fertilizers alone or in combination brought significant improvement in growth attributes, viz. plant height except 100% RDF through PM or NC and 75% RDF through NC + 25% RDF through fertilizers and branches/plant and yield attributes, viz. umbels/plant, umbellates/umbel except 100% RDF through FYM, seeds/umbellate and test weight over absolute control (Table 1). Obviously the control treatment where no manures and fertilizer were applied was significantly poor with respect to all growth and yield characters. The application of 100% RDF through fertilizers showed 12.3, 20.9, 29.7, 21.1, 37.1 and 12.5% increment in plant height, branches/plant, umbels/plant, umbellates/umbel, seeds/umbellate and test weight over absolute control, respectively. Application of recommended dose of nitrogen and phosphorus through fertilizers enhanced the availability of nutrients, which resulted in increased photosynthetic activity and translocation of photosynthates from source to sink and this might be the cause of higher growth and yield attributes. Patel *et al.* (2003) and Godara *et al.* (2014) also recorded higher growth and yield attributes when

Table 1 Influence of integrated nutrient management on growth and yield of cumin (Mean data of 3 Years)

Treatment	Plant height (cm)	Branches/ plant	Umbels /plant	Umbellates / umbel	Seeds/ umbellate	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
Control	30.0	4.3	15.8	3.8	19.4	4.24	270	832	1102
100% RDF[1] through fertilizers	33.7	5.2	20.5	4.6	26.6	4.77	442	1053	1496
100% RDF through FYM[2]	31.9	4.8	18.0	4.0	22.9	4.51	414	1056	1470
100% RDF through PM[3]	31.6	4.8	18.7	4.1	22.2	4.59	443	1053	1496
100% RDF through VC[4]	33.0	5.0	19.0	4.4	24.9	4.66	453	1155	1608
100% RDF through NC[5]	31.8	4.6	18.2	4.2	24.6	4.60	421	1067	1487
50% RDF through FYM +50% RDF through fertilizers	32.7	5.0	18.8	4.1	25.5	4.85	449	1149	1598
50% RDF through PM + 50% RDF through fertilizers	33.1	4.8	19.0	4.5	25.4	4.62	463	1199	1662
50% RDF through VC + 50% RDF through fertilizers	34.4	5.2	21.3	4.7	27.3	4.72	474	1221	1695
50% RDF through NC + 50% RDF through fertilizers	32.5	5.0	18.9	4.3	25.9	4.58	449	1153	1602
75% RDF through FYM + 25% RDF through fertilizers	32.5	5.0	18.2	4.2	25.7	4.59	453	1168	1621
75% RDF through PM + 25% RDF through fertilizers	32.6	4.9	18.2	4.4	24.8	4.71	460	1135	1596
75% RDF through VC + 25% RDF through fertilizers	33.5	5.1	19.4	4.5	26.0	4.71	466	1163	1629
75% RDF through NC + 25% RDF through fertilizers	31.7	4.8	18.3	4.2	24.2	4.52	416	1116	1532
CD (P=0.05)	0.7	0.1	0.4	0.1	0.5	0.08	15	36	47
SEm ±	1.9	0.3	1.1	0.3	1.5	0.23	42	102	134

[1]Recommended dose of fertilizer, [2]Farmyard manure, [3]Poultry manure, [4]Vermicompost, [5]Neem cake.

RDF was applied through fertilizers in cumin followed by integrated nutrient management. The plant height, branches/plant, umbels/plant, umbellates/umbel, seeds/umbellate and test weight were significantly increased with organic manures by 6.3, 11.6, 13.9, 5.3, 18.0 and 6.4% with 100% RDF through FYM; 5.3, 11.6, 18.4, 7.9, 14.4 and 8.3% with 100% RDF through PM; 10.0, 16.3, 20.3, 15.8, 28.4 and 9.9% with 100% RDF through VC and 6.0, 7.0, 15.2, 10.5, 26.8 and 8.5% with 100% RDF through NC over control, respectively. Moreover, organics, besides supplying macro and micronutrients, have also solubilizing effect on native soil nutrients due to the action of organic acids produced during decomposition and resulted in higher growth attributes. The organic manures also improve the availability of phosphorus which plays a unique role in energy conservation and transfer. Application of manures increased the supply of easily assimilated major as well as micronutrients to plants besides mobilizing unavailable nutrients into available form. The findings are supported by Tolanur (2009) and Singh (2011).

The integrated application of 50% RDF through VC + 50% RDF through fertilizers gave higher values of all the growth and yield attributes, *viz.* plant height (34.4 cm), branches/plant (5.2), umbels/plant (21.3), umbellates/umbel (4.7), seeds/umbellate (27.3) and test weight (4.72 g) to the magnitude of 14.7, 20.9, 34.8, 23.7, 40.7 and 11.3% over absolute control, respectively and closely followed by 100% RDF through fertilizers as well as 75% RDF through organic manures + 25% RDF through fertilizers. The combination of organic and fertilizer source of nutrients ensured ready availability of nutrients for initial requirement through fertilizers and slow pace as long-term availability through organic source throughout the crop growth period might have improved adequate biomass production and improvement in growth parameters. The combined effect of organic and fertilizer sources played a very important role due to their synergistic effect. Similar beneficial combined effect of organic and inorganic sources on growth parameters was also recorded by Singh and Verma (2002). The increased and balanced supply of nutrients to plants promotes flowering and fruiting and supply of food material and its subsequent partitioning in the sink. It also reduced leaf senescence and able to furnish the increased assimilate demand of plant sinks which resulted in higher yield attributes. The results corroborate the finding of Panwar and Munda (2007). Sunanda *et al.* (2014) recorded highest yield of Kasuri methi with 75% N + RD PK + FYM (7.5 t/ha) + *Rhizobium* (1.5 kg/ha) + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha). Contrary to our findings, Patel *et al.* (2013) recorded the maximum yield of cumin when RDF applied through fertilizers as compared to organic manures and integrated nutrient management.

Seed, straw and biological yields

On the basis of three year pooled analysis, it was found that the yields were significantly improved by application of organic manures or fertilizers alone or in combination with manures, viz. FYM, PM, VC and NC over the absolute control (Table 1). The 100% RDF through fertilizers significantly increased seed (442 kg/ha), straw (1 053 kg/ha) and biological yields (1 496 kg/ha) to the tune of 63.7, 26.6 and 35.8% over absolute control, respectively. The increased nutrient supply contributed to improvement of plant growth and development leading to higher yield as reported from fenugreek by Asaf *et al.* (2009). The seed, straw and biological yields of cumin were also significantly improved with organic manures registering 53.3, 26.9 and 33.4% with 100% RDF through FYM; 64.1, 26.6 and 35.8% with 100% RDF through PM; 67.8, 38.8 and 45.9% with 100% RDF through VC and 55.9, 28.2 and 34.9% with 100% RDF through NC over control, respectively. The organic sources supply not only the major nutrients but also minor nutrients which play crucial role in enzymatic reactions in rhizosphere of the plant and thus helped the plant to grow vigorously and to produce more yields. Vermicompost is also beneficial in improving the soil environment which in turn encourages proliferous root growth resulting in better absorption of moisture, nutrients and thus producing higher biomass. The significant differences in dry matter and seed yield may be attributed to the higher levels of nutrients besides growth stimulating substances (enzymes, antibiotics and growth hormones) available in vermicompost. Neem cake is known as high value manure having low C:N ratio that also possesses good pesticide and insecticidal properties. The growth promoting effect of FYM as a source of plant nutrients and humus improved the soil physiological condition by increasing its capacity to absorb and store water, improving aeration and favouring beneficial microbial activity in groundnut (Choudhary *et al.* 2011). Mahapatra *et al.* (2009) also reported beneficial effects of organic manures on sustainable crop production and soil fertility.

Among the different nutrient management, highest mean seed yield (474 kg/ha) was obtained with conjunctive use of 50% RDF through VC + 50% RDF through fertilizers which was comparable with 100% RDF through fertilizers (442 kg/ha), 100% RDF through PM (443 kg/ha), 100% RDF through VC (453 kg/ha), 50% RDF through FYM + 50% RDF through fertilizers (449 kg/ha), 50% RDF through PM + 50% RDF through fertilizers (463 kg/ha), 50% RDF through NC + 50% RDF through fertilizers (449 kg/ha), 75% RDF through FYM + 25% RDF through fertilizers (453 kg/ha), 75% RDF through PM + 25% RDF through fertilizers (460 kg/ha) and 75% RDF through VC + 25% RDF through fertilizers (466 kg/ha). However, seed yield recorded with 50% RDF through VC + 50% RDF through fertilizers was significantly higher over absolute control (270 kg/ha), 100% RDF through FYM (414 kg/ha), 75% RDF through NC + 25% RDF through fertilizers (416 kg/ha) and 100% RDF through NC (421 kg/ha) realizing the percent increase of 75.6, 14.5, 13.9 and 12.6, respectively. The straw (1221 kg/ha) and biological (1695 kg/ha) yields obtained with integrated use of 50% RDF through VC + 50% RDF through fertilizers were significantly higher over absolute control (832 and 1102 kg/ha) by 46.8 and

53.8%, 100% RDF through fertilizers (1 053 and 1 496 kg/ha) by 15.9 and 13.3%, 100% RDF through FYM (1056 and 1470 kg/ha) by 15.6 and 15.3%, 100% RDF through PM (1053 and 1496 kg/ha) by 15.9 and 13.3%, 100% RDF through NC (1067 and 1487 kg/ha) by 14.4 and 14.0% and 75% RDF through NC + 25% RDF through fertilizers (1 116 and 1 532 kg/ha) by 9.4 and 10.6%, but remained at par to rest of the treatments of organic manure (100% RDF through VC) as well as integration of both sources of nutrients. The positive response to combined application of organic manures and fertilizers might be attributed to the better nutrient availability and its favorable effect on soil physical and biological properties resulting in increased yield attributes and finally higher yields (Nambiar and Abrol 1989). The increased yield might also be due to better nutritional status of the soil which might have stimulated the rate of various plant physiological processes which led to increased growth and yield attributing characteristics and their cumulative effect resulted in enhanced seed, straw and biological yields of cumin. The results on yield thus confirmed the trend observed earlier in the yield attributing characters and upheld the need of supplementing the RDF through fertilizers with organic and emphasized the utter need for organic manuring along with chemical fertilizers. The increase in production of the crop due to integrated nutrient management was also reported by Tolanur and Badanur (2003). Singh (2011) recorded maximum biomass, seed and oil yield in coriander with the application of 7.5 t vermicompost + 25% recommended dose of NPK fertilizers. Contrarily, Godara *et al.* (2014) reported maximum seed yield of fennel with RDN (100%) applied through fertilizers closely followed by 50% RDN through fertilizers + 50% RDN through vermicompost but 50% RDN through fertilizers + 50% RDN through vermicompost recorded highest biological yield closely followed by 100% RDN through fertilizers.

Economics

The nutrient management had significant influence on the economics of cumin. Organic manures or fertilizers alone or in combination with manures significantly increased gross and net returns and benefit:cost ratio over absolute control (Table 2). All the net and gross return values were calculated on per hectare basis. The application of 100% RDF through fertilizers obtained ₹ 70 720 and 53 778 gross and net returns and 3.17 benefit:cost ratio which were significantly higher by 63.7, 96.3 and 83.2% compared to absolute control. Application of 100% RDF through FYM, PM, VC and NC

Table 2 Influence of integrated nutrient management on economics, volatile oil and soil fertility after harvest of cumin (Mean data of 3 years)

Treatment	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	Volatile oil (%)	Organic carbon (%)	Available N (kg/ha)
Control	43200	27400	1.73	3.02	0.18	124.8
100% RDF[1] through fertilizers	70720	53778	3.17	3.15	0.21	129.1
100% RDF through FYM[2]	66240	48942	2.83	3.10	0.28	138.8
100% RDF through PM[3]	70880	53315	3.04	3.13	0.25	138.2
100% RDF through VC[4]	72480	53465	2.81	3.25	0.24	141.6
100% RDF through NC[5]	67360	47150	2.33	3.07	0.25	137.5
50% RDF through FYM +50% RDF through fertilizers	71840	54719	3.20	3.11	0.25	145.2
50% RDF through PM + 50% RDF through fertilizers	74080	56827	3.29	3.20	0.24	141.1
50% RDF through VC + 50% RDF through fertilizers	75840	57861	3.22	3.26	0.23	145.3
50% RDF through NC + 50% RDF through fertilizers	71840	53264	2.87	3.15	0.22	140.6
75% RDF through FYM + 25% RDF through fertilizers	72480	55270	3.21	3.12	0.27	146.5
75% RDF through PM + 25% RDF through fertilizers	73600	56190	3.23	3.22	0.24	139.5
75% RDF through VC + 25% RDF through fertilizers	74560	56064	3.03	3.22	0.24	144.3
75% RDF through NC + 25% RDF through fertilizers	66560	47167	2.43	3.14	0.23	139.7
CD (*P*=0.05)	1677	1214	0.06	0.05	0.01	1.4
SEm ±	4852	3470	0.18	0.13	0.02	4.1

[1]Recommended dose of fertilizer, [2]Farmyard manure, [3]Poultry manure, [4]Vermicompost, [5]Neem cake.

also fetched significantly higher gross returns of ₹ 66 240; 70 880; 72 480 and 67 360 registering 53.3, 64.1, 67.8 and 55.9%, net returns of ₹ 48 942; 53 315; 53 465 and 47 150 registering 78.6, 94.6, 95.1 and 72.1% and benefit:cost ratio of 2.83, 3.04, 2.81 and 2.33 registering 63.6, 75.7, 62.4 and 34.7% increase over control, respectively.

Further, amongst integrated treatments, 50% RDF through VC + 50% RDF through fertilizers recorded highest gross (₹ 75 840) and net monetary returns (₹ 57 861) which was significantly superior to control (₹ 43 200 and 27 400) by 75.6 and 111.2%, 100% RDF through fertilizers (₹ 70 720 and 53 778) by 7.2 and 7.6%, 100% RDF through FYM (₹ 66 240 and 48 942) by 14.5 and 18.2%, 100% RDF through PM (₹ 70 880 and 53 315) by 7.0 and 8.5%, 100% RDF through VC (₹ 72 480 and 53 465) by 4.6 and 8.2%,100% RDF through NC (₹ 67 360 and 47 150) by 12.6 and 22.7% and 75% RDF through NC + 25% RDF through fertilizers (₹ 66 560 and 47 167) by 13.9 and 22.7%, however it remained at par to rest of the treatments of integration of organic and inorganic sources of nutrients. The more benefit:cost ratio (3.29) was obtained with 50% RDF through PM + 50% RDF through fertilizers very closely followed by 75% RDF through PM + 25% RDF through fertilizers (3.23), 50% RDF through VC + 50% RDF through fertilizers (3.22), 75% RDF through FYM + 25% RDF through fertilizers (3.21), 50% RDF through FYM + 50% RDF through fertilizers (3.20), 100% RDF through fertilizers (3.17) and 100% RDF through PM (3.04) whereas, significantly superior to control (1.73) and other treatments. The low returns and benefit cost ratio with organic manures might be due to higher cost of these sources with lesser yield compared to their integration with fertilizers. The lower quantity of fertilizers is required to fulfill the 100% RDF which resulted in lesser investment which ultimately gave the highest benefit cost ratio or higher returns per rupee investment over organic manures but organic manures offer benefits of enhancement of soil physical, chemical and biological properties over long term instead of meeting a part of nutrients need of the crop to sustain high yield. Earlier results reported by Singh and Verma (2002) supports the present findings. Similar studies done in other crops were also reviewed. Singh *et al.* (2013) found that 50% RDN through FYM + 50% through urea, 80% RDN through vermicompost + 20% through urea and 25% RDN through FYM + 75% through urea being at par with each other fetched significantly higher net returns and benefit:cost ratio from pearlmillet. However, in fennel 100% RDN applied through fertilizers exhibited highest net returns (₹ 62 091/ha) and benefit cost ratio (3.01), closely followed by 50% RDN through fertilizers + 50% RDN through vermicompost as recorded by Godara *et al.* (2014).

Volatile oil content in seed

Nutrient application either through organic manures or chemical fertilizes as well as their integrated use markedly improved volatile oil content in seed of cumin in comparison to control (Table 2). The 100% RDF through fertilizers significantly increased volatile oil content (3.15%) to the tune of 4.3% over absolute control (3.02%). Volatile oil content in seed was also significantly improved with 100% RDF through VC (3.25%) recording an increase of 7.6% over control. Maximum volatile oil content (3.26%) was observed with 50% RDF through VC + 50% RDF through fertilizers which was at par with 100% RDF through fertilizers, 100% RDF through PM and VC, 75% RDF through PM, VC and NC + 25% RDF through fertilizers and 50% RDF through PM and NC + 50% RDF through fertilizers but significantly superior to rest of the treatments. This treatment registered 7.9% increase over absolute control. Improvement of quality of cumin can be attributed to improvement in soil physical, chemical and biological properties which might have led to better root proliferation, improved nutrient uptake and better accumulation of photosynthates, while as in case of chemical fertilizers the lower values of volatile oil content in comparison to integrated treatments could be attributed to the fact that these are source of only few essential nutrients. The superiority of integrated nutrient management can also be attributed to their effect on better seed development. Contrary to this, it was reported that volatile oil content was not influenced by organic and inorganic fertilizers in coriander (Singh *et al.* 2011) and cumin (Patel *et al.* 2013).

Soil fertility status

The data in Table 2 indicated that after harvest of cumin, the organic carbon and available nitrogen in soil markedly improved due to organic manures, fertilizers and all combinations of organic manures and fertilizers over control. Further, addition of nutrients, either only through organic manures or in combination with fertilizers in different proportions, increased the organic carbon and available nitrogen in soil over 100% RDF only through fertilizers. Application of 50% RDF through organic + 50% RDF through fertilizers, 75% RDF through organic + 25% RDF through fertilizers and 100% RDF through organic, i.e. FYM, PM, VC and NC enhanced progressively organic carbon content of the soil over the initial content. Contrary to this, available nitrogen increased progressively from 100% RDF through organic sources alone towards integrated use of organic and fertilizers sources. The significantly highest values of organic carbon (0.28%) was recorded with 100% RDF through FYM, whereas 75% RDF through VC + 25% RDF through fertilizers indicated highest available nitrogen balance (146.5 kg/ha) followed with 50% RDF through VC + 50% RDF through fertilizers (145.3 kg/ha). Organic manure has got some solubilising effect on some mineral compounds present in soil and brings about the conversion of a number of chemical elements in available form. The beneficial effect of organic manures on organic carbon content could be attributed to the presence of higher residue and litter and enhanced microbial activity. The improvement in soil fertility after crop harvest due to integrated nutrient management was also recorded by Parihar and Rana (2010). The increase in the availability of nitrogen in soil under the treatments having combination of chemical fertilizers and manures might have enhanced organic matter due to application of organic manure, besides reducing losses of nitrogen. Singh *et al.* (2013) reported highest organic carbon and available soil nitrogen in pearlmillet cultivation with 100% RDN through FYM followed by 80% RDN through vermicompost + 20% through urea and integrated use of RDN through FYM + urea in different proportions.

The nutrients play an important role in the crop production but under intensive use of chemical fertilizers alone for long period could result in deterioration of soil fertility and quality of produce. The use of organic manure in combination with fertilizers helps in balancing soil fertility, environment and reduce the cost of inputs as reported by several workers. Therefore, from present study it is recommended to apply 50% RDF through VC + 50% RDF through fertilizers for realizing higher productivity, quality of produce and net monetary returns from cumin along with improvement in soil health.

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