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Effect of wool waste in conjunction with FYM and inorganic fertilizer on growth and yield of cabbage (*Brassica oleracea* var. capitata)

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Abstract
The present investigation was conducted during *rabi* season of 2015-16 at the Agriculture Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan) to study the effect of wool waste in conjunction with FYM and fertilizer on growth and yield of cabbage. The treatments consisted four levels of organic material control (W_0), 7.5 t ha^{-1} each wool waste and FYM (1:1) (W_1), wool waste @ 5 t ha^{-1} + FYM @ 10 t ha^{-1} (1:2) (W_2) wool waste @ 3.75 t ha^{-1} + FYM @ 11.25 tha^{-1} (1:3) (W_3)and FYM @ 15 t ha^{-1} (W_4), four levels of recommended dose of fertilizer (0, 75, 100 and 125% NPKS). The experiment was replicated thrice in a split plot design. Results of the experiment revealed that the head weight, perimeter of head, head yield and Stover yield of cabbage were significantly higher due to application of wool waste @ 7.5 t ha^{-1} along with FYM @ 7.5 t ha^{-1} and 125 % recommended dose of fertilizer (W_1F_2) compared to rest of the treatments.

Keywords: INM, wool waste, FYM, growth and yield of cabbage

Introduction

Cabbage (*Brassica oleracea var. capitata* L.) is most important member of the genus brassica grown in the world belonging to family Crucifereae (*Brassicaceae*). It is the most popular vegetable around the world in respect of area, production and availability (Smith, 1995) [16]. However, it's cultivation is equally successful in the tropical and sub- tropical regions. Cabbage is an important leafy vegetable in India. It is rich in minerals and vitamins, contains vitamin-A (2000 IU), thiamine (0.06 mg), riboflavin (0.03 mg) and vitamin C (124 mg) per 100 g edible part. It also contains minerals like potassium (114 mg), phosphorus (44 mg), calcium (39 mg), sodium (14.1 mg) and iron (0.8 mg) per 100 g of edible part (Fageria *et al*. 2003) [5]. Now a day it is the most popular vegetable around the world in respect of salad, boiled, cooked, curing, pickling and dehydration purpose (More, 2006) [13]. It neutralizes acidity and improves digestion and appetite (Katyal and Chadha, 1985) [12]. The Food and Agriculture organization (FAO, 1988) has identified cabbage as one of the top twenty vegetables and an important source of food globally. Many countries have incorporated cabbage as part of their national cuisine (Olaniyi *et al.* 2008) [15]. The major cabbage growing states in India are Orissa, West Bengal, Uttar Pradesh, Bihar, Karnataka, Maharashtra, Gujarat, Punjab and Himachal Pradesh (Fageria *et al*. 2003) [5]. In India it is grown in 3.72 lac. Ha area with 85.34 lac tonne production and 229 qt ha^{-1} productivity whereas, in Rajasthan is grown in 1190 ha area with 5.69 thousand tonnes production and 4.78 qt ha^{-1} productivity (NHB, 2013).

Farm yard manure (FYM), in general add nutrients as well as improve physio-chemical properties of soil for proper growth & development of crop. Besides, addition of O.M. also improves the soil texture by binding effect. Organic manure increases CEC, water holding capacity and phosphate availability of the soil, besides improving the fertilizer use efficiency and microbial population of soil; it reduces nitrogen loss due to slow release of nutrients and fulfills the nutrients requirement of plants for longer period. Wool waste is richer in organic N (over 5%) and C (30-50%) than manure and compost (Baker, 1991) [4]. Their elemental analysis shows fairly similar percentages of carbon (around 50 mass %), hydrogen (7 mass %), oxygen (22 mass %), nitrogen (16 mass %) and sulphur (5 mass %). Sheep wool hydrolyzate improves growing conditions, by increasing total N, C and P content in the soil (Govi *et al*. 1998) [7]. Applied hydrolyzed wool also improved seed emergence and plant growth (Nustorova *et al*. 2006) [14].

Rajasthan specially the Bikaner district is one of the highest sheep and wool producing area in the country. There are about 163 woolen mills in Bikaner, manufacturing 1.5 lakhs kg of Carpet woollen yarn per day during processing period and releasing a huge quantity of wool waste, approximately 4-5% of total woollen production. Mainly the wool waste is generated from `Opener Section' of woollen industry. One of the main qualities of wool is biodegradability, which means that when buried into soil, the keratin biopolymer is degraded by microorganisms and releases nutrients essential to the crops. Wool is quite resistant to the attack of microorganisms, which are able to breakdown the keratinous fibre only in hydrophilic conditions. The degradation is obvious in terms of months; the representative functional groups of wool start to degrade and convert into biomass after 4 weeks, and in hydrophilic conditions, the weight loss is 33% in three months (Arshad and Mujahid, 2014) [2]. The extreme nature of climate & sandy soil loss from the cultivation of the crop Hence, wool waste, FYM & fertilizer could be an at most option to get maintain yield because wool waste slowly decomposes in soil it can be used as a slow-release fertilizer, and will act as a source of nitrogen-based nutrients and sulfur over a much longer period than conventional fertilizers. Low grade raw wool or wool waste can be used as agricultural amendments, layer directly in the bottom of the planting pits, or added to the compost mixture, to improve the nitrogen content and water retention. Wool in non-woven form can also be used as weed mats, which initially inhibit weed growth & slowly break down to release nutrients for the crops (Hempe, 2014) [11]. The productivity could be sustained through integrated use of organic and inorganic fertilizers.

Materials and Methods

An experiment was conducted during Rabi season of 2015-16 at the Agriculture Research Station, SKRAU, Bikaner, Rajasthan (28° 01' N, 73° 22' E and 234.7 m above sea level). The soil of the experimental field was sandy in texture, low in organic carbon, nitrogen, phosphorus, iron and zinc, and medium in potash. The physico-chemical and biological properties of the soil is depicted in Table 1. Wool waste and FYM were applied as per treatments combination before one month of transplanting. The dose of N, P_2O_5, K_2O and S were applied through urea, diammonium phosphate, murate of potash and elemental suphur, respectively as per the treatment combination. Half dose of N, full dose of P and K were applied as basal in the form of urea, di-ammonium phosphate and muriate of potash at the time of transplanting. The remaining N was applied after 30 days of transplanting. Sulphur was applied as per treatment combination @ 40 kg ha^{-1} through elemental sulphur before 10 days of transplanting.

To raise nursery beds of 5x2 square meter in size was prepared by mixing well rotten FYM in soil at the rate of 15 kg per square meter. Seeds of cabbage Valina hybrid obtained from private agency and treated with 0.02% thiram to check the infection of damping off and seed borne diseases. Seeds were sown on 24th Oct, 2015 in shallow furrows 10-15 cm apart by dropping the seeds at 5-8 cm apart and at 1.5-2.0 cm depth. A thin layer of powdered leaf mould was applied to cover the seed. Regular watering, hoeing, weeding, plant protection measures, etc. were done time to time. The seedling was ready for transplanting within 4 weeks.

Table 1: Initial physico-chemical and biological properties of the experimental field

pH	EC (dSm^{-1})	Particle Density ($Mg\ m^{-3}$)	Bulk Density ($Mg\ m^{-3}$)	Water holding capacity (%)	Saturated hydraulic Conductivity ($cm\ hr^{-1}$)	OC (%)	Available macronutrient concentration ($kg\ ha^{-1}$)				DTPA extractable Micronutrient (ppm)				Dehydrogenase activity μg TPF g^{-1} soil 24 hr^{-1}	Fungi count ($10^4 cfu\ g^{-1}$ soil)	Bacteria count ($10^5 cfu\ g^{-1}$ soil)
							N	P_2O_5	K_2O	S	Zn	Cu	Mn	Fe			
8.55	0.10	2.63	1.58	8.45	12.27	0.16	89.24	27.64	224.29	21.92	0.97	0.42	7.42	6.60	65.71	8.75	12.01

Results and Discussion

Result from this study suggests that wool waste is an excellent nutrient source for cabbage crop. Analysis of wool showed that it contain good amount of all nutrients required by plants (Table 2) and almost all nutrients showed their positive effect except few like phosphorus and potassium.

Table 2: The elemental concentration of wool waste used in field experiment

Parameter	This study	Literature			
		Wool @	Wool #	Wool $	Wool ^
C	179.2 g/kg	293 g/kg	-	-	296 g/kg
N	23.72 g/kg	1.08 g/kg	15.78 %	-	1.10 g/kg
P	0.303 ppm	805 ppm	0.0137 %	148 – 284 ppm	125 ppm
K	7.55 g/kg	32980 ppm	45 ppm	643- 755 ppm	187 ppm
S	21.7 g/kg	51.3 g/kg	3.21 %	18733.4 – 22038ppm	32.10 g/kg
Zn	94.25 ppm	501 ppm	115 ppm	73.6 – 88.80 ppm	230 ppm
Cu	13.39 ppm	8 ppm	25 ppm	5.30 – 10.30 ppm	8.54 ppm
Mn	45.93 ppm	21 ppm	25 ppm	3.37 – 22.93 ppm	8 ppm
Fe	914.96 ppm	234 ppm	50 ppm	22.03- 513.17 ppm	12.47 ppm

C and N analyzed by CNHS analyzer, Soil testing lab, CAZRI, jodhpur, P and S analyzed by spectrophotometer and K is analyzed by flame-photometer, Laboratory of STCR-Project, ARS, beechwal, Bikaner and micronutrients were analyzed by AAS, Government soil testing laboratory, 24 paota, Jodhpur

@ Wool mineral content as reported by Zheljazkov VD, 2005 [19].

Wool mineral content as reported by RH Burns *et al*. 1964.

$ Wool mineral content as reported by Bozena Patkowska-Sokola *et al*, 2009 [17].

^ Wool mineral content as reported by Sharma *et al*. (2014) [9]

Growth and yield attributes

Perimeter of Head

A glance in the data on perimeter of cabbage head show that application of organic materials and fertilizer levels has significantly increased the perimeter of cabbage head. The maximum perimeter of cabbage head (52.04 cm) was recorded with W_1 treatment and followed by W_2, W_3 and minimum with W_0 treatment. Significant increase in perimeter of cabbage head was observed with every increased dose of fertilizer. Maximum perimeter value was recorded as 50.76 cm with F_3 i.e. 125 per cent recommended dose of fertilizer.

Table 3: Effect of wool waste in conjunction with FYM and fertilizer on Growth & Yield attributes of cabbage

Treatments	Perimeter of head (cm) (average of 5 head)	Head weight (kg) (5 plants per plot)	Head yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Organic materials (t ha^{-1})				
W_0	39.00	5.71	15480.10	8311.45
W_1	52.04	9.46	28044.69	13113.18
W_2	46.73	9.03	25147.08	12579.78
W_3	44.90	8.94	23642.17	11664.56
W_4	43.93	8.73	23008.85	10039.83
S Em ±	1.60	0.30	455.28	358.80
CD at 5%	5.21	0.97	1484.74	1170.11
Fertilizer Levels (kg ha^{-1})				
F_0	36.86	5.67	16777.64	9102.22
F_1	44.64	7.30	22257.19	10842.81
F_2	49.02	10.19	26098.33	12006.25
F_3	50.76	10.33	27125.15	12615.76
S Em ±	0.96	0.24	357.19	258.86
CD at 5%	2.78	0.69	1031.63	747.64

Table 4: Combined effect of wool waste in conjunction with FYM and chemical fertilizer on head yield of cabbage

W x F	Organic materials (t ha^{-1})				
	W_0	W_1	W_2	W_3	W_4
Fertilizer Levels (kg ha^{-1})					
F_0	11500.0	19178.5	17798.7	17796.0	17615.0
F_1	14312.0	26242.9	25258.7	23256.7	22215.7
F_2	16881.7	33180.6	28384.7	26443.3	25601.3
F_3	19226.7	33576.8	29146.3	27072.7	26603.3
CD-I at 5%	1484.74				
CD-II at 5%	1186.97				

Effect of wool waste @ 7.5 t ha-1 and FYM @ 7.5 t ha-1 with different fertilizer levels on cabbage crop

Head weight (5 head per plot)

Data pertaining to head weight during the experimental year recorded just before harvesting of cabbage crop as influenced by wool waste in conjunction with FYM and different fertilizer levels is presented in table 3. Data clearly shows positive effect of different organic materials on head weight just before harvest of cabbage crop. Treatment W_1, W_2, W_3 and W_4 with a value of 9.46, 9.03, 8.94 and 8.73 kg were significantly superior over control W_0 with a value of 5.71 kg. Moreover, W_2, W_3 and W_4 were at par with each other with regard to effect of organic materials on head weight.

Increasing dose of fertilizer resulted in increase of head weight with each level being significantly different from other. Application of 125 per cent recommended dose of fertilizer gave head weight of 10.33 kg which was significantly higher to control and F_1 treatment. However, at par with F_2 level of fertilizer.

Head and Stover yield of cabbage

Maximum head yield was recorded as 28044.69 kg ha^{-1} with W_1 i.e. wool waste @7.5 t ha^{-1} with conjunction of FYM @ 7.5 t ha^{-1}. Head yield decreased with decreasing proportion of wool waste. Significant increase in head yield of cabbage was observed with every increase dose of RDF. Maximum head yield was obtained 27125.15 kg ha^{-1} with F_3 i.e. 125 per cent recommended dose of fertilizer. Combined application of organic materials and fertilizers significantly influenced the head yield. With increasing dose of fertilizer resulted significant improvement in head yield. Maximum head yield was recorded 33576.8 kg ha^{-1} with W_1F_3 i.e. wool waste @ 7.5 t ha^{-1} in conjunction with FYM @ 7.5 t ha^{-1} with 125 per cent recommended dose of fertilizer, followed by 33180.6 kg ha-1 with W1F2 and 29146.3 kg ha-1 with W2F3 (Table 4). Zheljazkov *et al*. (2009) [18] also considered the use of uncomposted wool waste as a nutrient source for both container grown plants, crops and field crops, reporting research that suggested wool waste may be an excellent soil amendment, providing increases in plant yields and essential oil content. Emma Kate Pugh [6] confirmed increases in plant yields of up to 28% dry matter weight. It also interestingly notes that wool 'seems to have greater imbibitions for water since soil moisture content at harvest was greater in soils than without wool amendment.

Similar trend was also observed in stover yield of cabbage. Treatment W_1, W_2, W_3 and W_4 with value of 13113.18, 12579.78, 11664.56 and 10039.83 kg ha^{-1} were significantly superior over control W_0 with a value of 8311.45 kg ha^{-1}. Application of 125 per cent recommended dose of fertilizer gave stover yield of 12615.76 kg ha^{-1} which was significant higher to control and rest of the treatments. Order of organic materials in influencing the head yield of cabbage was as follows $W_1>W_2>W_3>W_4>W_0$. Observation and documentation made by different researcher and scientists like Aktar *et al*. (1996) [1]; Azad (2000) [3]; Haque (2000) [10]; Souza *et al*. (2008) [18], are also supportive of the present findings who reported that when organic manure is used in the soil, some metallic trace elements stimulated root growth that ultimately increases the yield of crop.

Conclusion

On the basis of results of present investigation it can be concluded that combined application of wool waste @ 7.5 t ha^{-1} and FYM @ 7.5 t ha^{-1} along with 125 per cent recommended dose of fertilizer provide maximum growth & yield for cabbage crop. Therefore, this treatment combination can be suggested for better growth, yield attributing characteristics of cabbage.

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