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EFFECTS OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF MAIZE (*ZEA MAYS* L.) - GOBHI SARSON (*BRASSICA NAPUS* L.) CROPPING SYSTEM IN SUB-TROPICAL REGION UNDER FOOTHILLS OF NORTH-WEST HIMALAYAS

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Abstract

A pronounced residual effect of organic and inorganic fertilizers, applied in maize crop was observed on yields of maize-gobhi sarson cropping system. The experiment was conducted with 10 treatments of N, P, K, FYM, crop residue and zinc sulphate nutrients. The highest growth, yield and yield components of maize crop were recorded with 100% recommended fertilizer dose-RFD + $ZnSO_4$ 20 kg/ha and the grain yield (2409 kg/ha) was about 101% higher over the control. In case of gobhi sarson, the highest seed yield (1081 kg/ha) was observed as a pronounced residual effect of 10 t/ha FYM in preceding maize crop; which was about 81% higher over the control. The treatments where 50% N was substituted by FYM and crop residue in maize crop had the best reflection in enhancing the seed yield of gobhi sarson to the tune of 74 and 70% over the control and 16 and 13% over farmer's practice. The highest rain water use efficiency (RWUE) and heat-use efficiency (HUE) was recorded in treatment 100% RFD + $ZnSO_4$ 20 kg/ha in maize crop and 10 t/ha FYM in gobhi sarson.

Introduction

Rapeseed-mustard is grown on an area of 5.53 mha with production and productivity of 6.41 mt and 1157 kg/ha, respectively in India (Anon. 2010). About 12% of the total area of Jammu region constituting dry semi-hilly belt is rainfed in nature, the most stressed ecosystem of this region and is locally known as *kandi* area (Abrol *et al*. 2007). Maize-wheat is the most prevalent cropping sequence being practiced by farming community of *kandi* belt in Jammu (under rainfed conditions). Gobhi sarson crop has emerged as potential replacement for wheat as this crop has wider adaptability and could suitably exploit residual moisture of rainy season. Heat use efficiency (HUE), *i.e*., efficiency of utilization of heat in terms of dry matter accumulation is an important aspect, which has practical utility as reported for soybean and pigeonpea (Balakrishanan and Natarajaratnam 1986). Rao *et al.* (1999) reported that the total heat energy available to any crop is never completely converted to dry matter even under the most favourable agroclimatic conditions.

Increase in productivity of maize-based cropping system with integrated use of farmyard manure and chemical fertilizer has been widely reported (Kumpawat 2004, Jamwal 2005). As both the crops are highly exhaustive and thus fertility of the soil is depleted due to the presently lower quantity of fertilizer application by farmers of *kandi* region. In general, scheduling of fertilizers is based on the individual nutrient requirement of the crop and the carry over effect of manure and fertilizer applied to preceding crop is ignored (Panwar 2008). In sub-tropical *kandi* belt, generally organic manures like FYM, crop residues, or green manuring etc are applied to the crops in *kharif* season due to the availability of adequate amount of moisture as during *rabi* season moisture is the main limiting factor due to almost negligible rainfall in October-December months. Judicious use

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of organic matter can stabilize the productivity and sustainability of maize-gobhi sarson system. Since the information on this aspect is lacking in the region, the present study was initiated to assess the appropriate (organic and inorganic) nutrient management for maize-gobhi sarson cropping system.

Materials and Methods

Experiments were performed at Research farm, DLRSS, Rakh Dhiansar, SKUAST-J, Jammu and Kashmir state (32° 39" N 74° 53" E 332 m amsl), India in *kharif* (June - September) and *rabi* (October - March) seasons of 2006-07, 2007-08 and 2008-09 under rainfed conditions. The soil of the experimental site was sandy loam having low available N (110 to 209 kg/ha), P (12 to 16 kg/ha), K (106 to 180 kg/ha) and pH 6.8 to 7.2. The treatments comprised of T_1: Control; T_2: 100 % recommended fertilizer dose-RFD (60 : 40 : 20 NPK kg/ha); T_3: 50% RFD; T_4: 50% N (crop residue); T_5: 50% N (FYM); T_6 : 50% RFD + 50% N (crop residues); T_7 : 50% RFD + 50% N (FYM); T_8 : FYM 10 t/ha; T_9: 100% RFD + $ZnSO_4$ 20 kg/ha and T_{10} : Farmers practice (FYM 4 t/ha + urea 40 kg/ha). Maize (var. *Mansar*) was sown on 29 June, 2 July and 29 June and harvested on 24 September, 1 October and 26 September for the *kharif* seasons of 2006, 2007 and 2008, respectively. Whereas, gobhi sarson (var. *DGS*-1) was sown on 14, 16 and 16 October and harvested on 9, 11 and 1 April for the *rabi* seasons of 2006-07, 2007-08 and 2008-09, respectively. Maize and gobhi sarson crops were sown in lines in a unit plot size of 6 m × 4 m with a spacing of 60 cm × 20 cm and 30 cm × 20 cm, respectively. All the treatments were applied in maize crop and the left over effects were studied in gobhi sarson crop. A total rainfall of 630.0, 859.8 and 692.1 mm in 24, 32 and 28 rainy days was received during *kharif* and 308.8, 175.0 and 110.4 mm in 18, 11 and 15 rainy days during *rabi* in the respective years of cultivation. Urea, diammonium phosphate, muriate of potash and gypsum were used as a source of nitrogen, phosphorus, potassium and sulphur, respectively. Maize equivalent yield (MEY) was computed by converting the gobhi sarson yield into the yield of maize on the basis of the prevailing market prices of individual crop. Weather data was recorded at Meterological Observatory, DLRSS, Rakh Dhiansar and the following agro-meteorological indices were calculated:

(a) Accumulated heat unit (∑HU): The accumulated heat units were calculated by adopting the formula given by Nuttonson 1955.

$$HU = \frac{\sum_a^b [T\ max + T\ min] - T_b}{2}$$

where, T max = Maximum temperature (ºC) during a day; T min = Minimum temperature (ºC) during a day and T_b = Base temperature 8 and 5ºC for maize and gobi sarson crops, respectively under sub tropical conditions

a starting date of phenophase of interest; b ending date of phenophase of interest.

(b) Heat use efficiency (HUE): HUE is the ratio of dry matter (kg/ha) to the cumulative heat unit to attain the phenophases.

$$HUE\ (kg/ha/^oC/day) = \frac{Dry\ matter\ (kg/ha)}{Cumulative\ heat\ unit\ (^0C\ days)}$$

The statistical analysis was done by using SPSS16 and OPSTAT software.

Results and Discussion

Recommended fertilizer dose (100% RFD) along with $ZnSO_4$ 20 kg/ha (T_9) in *kharif* season recorded statistically highest all growth and yield components of maize under three years of experimentation. The growth and yield component values of maize obtained with T_2 treatment were followed by the treatments T_7 and T_6 and both the treatments were statistically at par also. However, control plots experienced the lowest values of growth and yield components of maize (Table 1).

Organic matter applied to preceding maize crop had a positive residual effect on gobhi sarson which improved yield attributes of plants raised in plots that had experienced substitution of nutrients through organic sources in the preceding maize. The values for various growth and yield attributing characters like plant height, primary branches, secondary branches, pod length, seeds/pod and pods/plant statistically differed for residual effects of the various treatments imposed in preceding maize crop in three years under experimentation (Table 2). Control plots recorded the lowest values in all the three years under study. Treatment T_8 evinced significantly higher values of all growth and yield attributing characters than the first two best treatments of preceding season *i.e.*, T_9 and T_2 during all the years under study and on pooled basis. It was followed by statistically same T_7 and T_6 treatments. However, values obtained with farmer's practice (T_{10}) treatment were also statistically comparable. It may be due to presence of highly persistent material, *i,e*., cellulose in FYM which required longer time for complete decomposition. Thus nutrients released from FYM for longer period had notable benefits on the succeeding gobhi sarson crop. These results are in the line with those of Panwar (2008).

Maximum maize grain and biological yield of 2409 and 7668 kg/ha was recorded in T_9 treatment; however, it exhibited statistical parity with T_2 treatment which obtained 2136 and 6845 kg/ha grain and biological yield of maize crop, respectively. Treatment T_9 registered 108, 96, 97 and 101% increase over control and 33, 36, 36 and 35% increase over farmers practice during three years under study and on pooled basis, respectively. The results of increase in maize yield with application of Zn in addition to inorganic fertilizers were found in consistent with the findings of Kumwenda *et al.* (1996). The application of N, P and K fertilizer at optimal level might have made more nutrients available to the maize crop which reflected into higher grain yields by the application of 100% RFD + $ZnSO_4$ 20 kg/ha and 100% RFD alone. The results are also in consistent with the findings of Abrol *et al*. (2007). Treatment T_7 and T_6 produced maize grain yield of 2008 and 1879 kg/ha, which were about 17 and 22 and 6 and 12% less than the grain yield values recorded with the treatments T_9 and T_2, respectively on pooled basis (Table 3). The results are in line with the findings as reported by Pathak and Singh (2002). There was a statistically significant influence on seed and biological yield of gobi sarson as a residual impact of different sources and diverse modes of nutrition applied in previous maize crop in *kharif* season. Treatment T_8 observed significantly higher seed and biological yield of gobi sarson to the tune of 1081 and 5801 kg/ha (mean values) and it was also higher than the treatments receiving 100% RFD alone or with $ZnSO_4$ 20 kg/ha in maize crop. Treatments T_9 and T_2 registered about 22 and 25% less seed yield of gobhi sarson than T_8; whereas, about 5 and 9% less seed yield of gobi sarson was observed than farmer's practice (T_{10}), respectively. Integration of organic and inorganic; *i.e.* T_7 and T_6 registered about 74 and 70 and 87 and 77% increase of seed and biological yield of gobi sarson over control, respectively. The increase in yield with addition of FYM alone or in combination of inorganic fertilizers may be attributed to the fact that FYM being the store house of nutrients also made release of applied nutrients at its optimum at the same time improved the soil physical conditions (Kumar *et al*. 2002). FYM application also enhanced population of stimulated nitrogen fixing and phosphate solubilizing microorganisms and thus increased availability of plant nutrients in steady manner (Gaur 1998). The system productivity in

Table 1. Growth and yield attributes of maize under integrated nutrient management.

Treatments	Plant height (cm)			Cob length (cm)			Cob girth (cm)			Stem girth (cm)			Grains/cob			Seed-index (100 seed weight)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
T_1	206.4	195.4	169.6	8.3	7.9	7.3	6.2	5.6	5.0	3.3	3.1	3.0	80.5	71.2	64.5	15.8	15.4	15.2
T_2	248.2	231.5	207.9	16.8	16.3	15.8	15.0	14.1	13.7	6.7	6.4	6.0	256.3	246.5	220.6	23.4	22.8	22.4
T_3	227.8	213.5	185.2	14.6	14.2	13.9	12.9	12.6	12.4	5.5	5.4	4.9	203.7	188.2	170.2	21.7	22.1	21.8
T_4	226.6	210.4	180.1	14.0	13.7	13.1	12.3	11.6	11.0	5.4	5.2	4.7	196.2	181.4	162.5	19.9	19.5	19.0
T_5	220.2	206.4	174.3	12.4	12.1	11.6	10.6	10.2	9.9	4.8	4.5	4.1	154.5	132.6	111.5	18.9	18.6	18.1
T_6	235.9	218.9	193.9	15.7	15.2	14.7	13.9	13.4	12.9	6.0	5.8	5.3	228.3	203.5	182.4	22.6	22.1	21.5
T_7	237.9	221.2	198.3	16.3	15.9	15.2	14.3	13.6	13.0	6.3	6.0	5.6	245.8	226.3	203.2	23.1	22.5	21.9
T_8	225.4	208.5	177.1	13.5	13.1	12.5	11.6	11.1	10.5	5.0	4.7	4.2	190.1	172.4	155.6	19.4	18.7	18.1
T_9	258.4	243.9	216.3	17.5	17.0	16.6	15.2	14.4	13.8	7.0	6.6	6.2	275.0	258.9	250.2	23.7	23.1	22.6
T_{10}	232.0	217.3	189.9	15.2	14.6	14.1	13.0	12.5	12.0	5.7	5.5	5.0	224.5	201.4	178.9	22.2	21.5	21.0
Mean	231.9	216.7	189.3	14.4	14.0	13.5	12.5	11.9	11.4	5.6	5.3	4.9	205.5	188.2	170.0	21.1	20.6	20.2
CD ($p = 0.05$)	20.4	23.6	28.7	2.6	2.4	2.1	4.1	4.6	3.9	0.56	0.43	0.51	30.5	25.2	32.7	3.1	4.1	4.4
SE (m)	9.6	10.2	9.8	0.91	0.80	0.72	1.8	1.6	1.3	0.19	0.15	0.18	10.5	8.7	11.2	1.1	1.4	1.5
CV (%)	8.5	9.1	10.4	12.6	12.9	10.7	19.5	16.6	13.4	6.9	5.5	7.15	10.2	9.2	13.2	10.1	13.7	14.8

Table 2. Growth and yield attributes of gobhi sarson as affected by residual effects of integrated nutrient management.

Treatments	Plant-height (cm)			Primary branches			Secondary branches			Pod-length (cm)			Seeds/pod			Pods/plant		
	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09
T_1	101.8	86.5	81.0	6.3	5.8	5.2	5.2	4.8	4.1	7.0	6.8	6.0	23.2	20.5	16.6	174	152	109
T_2	119.2	103.5	100.5	7.5	7.1	6.3	6.5	5.9	5.3	7.6	7.4	6.7	28.0	25.0	19.7	210	203	169
T_3	115.4	95.2	100.2	7.1	6.8	6.0	6.3	5.5	5.0	7.4	7.2	6.5	27.2	23.7	18.8	198	189	160
T_4	111.2	92.6	96.8	6.9	6.5	5.7	6.0	5.2	4.7	7.4	7.1	6.5	26.5	22.8	17.9	186	173	135
T_5	129.2	114.0	116.5	8.5	7.9	6.8	7.3	6.6	5.8	8.0	7.5	6.8	29.4	27.1	20.8	243	229	192
T_6	138.5	126.9	123.4	9.2	8.9	7.5	8.3	7.2	6.8	8.2	7.9	7.1	31.2	28.8	23.0	276	251	217
T_7	140.2	133.5	127.2	9.6	9.3	7.8	8.5	7.6	7.0	8.4	7.9	7.3	32.0	29.3	23.7	288	264	224
T_8	145.7	138.8	132.8	10.1	9.2	8.0	9.1	8.0	7.3	8.4	8.0	7.3	32.9	30.8	24.4	309	278	226
T_9	122.0	107.5	110.1	8.0	7.4	6.6	6.9	6.1	5.6	7.9	7.4	6.8	28.8	26.4	20.3	228	213	185
T_{10}	131.6	122.5	120.2	8.7	8.3	7.2	7.7	6.9	6.1	8.0	7.7	7.0	30.6	28.0	22.2	254	242	203
Mean	125.5	112.1	110.9	8.2	7.7	6.7	7.2	6.4	5.8	7.8	7.5	6.8	29.0	26.2	20.7	237	219	182
CD (p = 0.05)	23.8	14.3	13.0	1.2	1.0	0.77	1.0	0.7	0.6	0.2	0.4	0.3	3.0	2.4	1.6	46.7	26.4	32.1
SE (m)	8.2	4.9	4.5	0.40	0.35	0.26	0.4	0.2	0.2	0.1	0.1	0.1	1.0	0.8	0.6	15.9	9.1	11.0
CV (%)	12.9	8.7	8.1	9.7	9.1	7.8	9.8	7.4	7.8	2.1	3.5	3.4	7.2	6.3	5.3	13.5	8.3	12.1

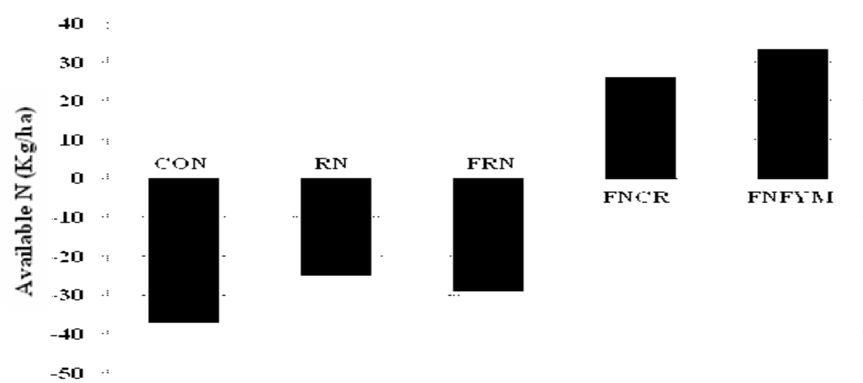
Table 3. Effect of integrated nutrient management on grain, biological yield of maize and gobhi sarson and maize equivalent yield (MEY) of the system.

Treatments	Grain yield (kg/ha)						Biological yield (kg/ha)						MEY (system) (kg/ha)		
	Maize			Gobi sarson			Maize			Gobi sarson					
	2006	2007	2008	2006-07	2007-08	2008-09	2006	2007	2008	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09
T_1	1250	1215	1133	697	650	443	3950	4023	4184	3360	3058	2180	2761	2599	2125
T_2	2267	2167	1975	983	923	537	6797	6783	6956	5365	4932	2778	4442	4167	3245
T_3	1685	1622	1558	900	857	513	5168	5203	5750	4336	4645	2503	3637	3439	2742
T_4	1668	1617	1508	870	760	477	5121	5188	5407	4611	3778	2337	3560	3251	2608
T_5	1602	1367	1300	1040	997	607	4935	4463	5050	5546	5220	3244	3817	3421	2634
T_6	2083	1867	1687	1220	1150	673	6283	5913	6281	6284	5532	3423	4699	4264	3191
T_7	2100	2083	1842	1223	1163	730	6330	6542	6917	6512	5639	3946	4724	4528	3477
T_8	1667	1583	1433	1243	1207	793	5117	5092	5211	6766	6413	4224	4283	4057	3117
T_9	2603	2392	2233	1013	970	570	7739	7436	7828	5067	5011	2836	4873	4504	3599
T_{10}	1950	1757	1642	1037	1013	637	5910	5594	6011	5799	5457	3356	4195	3884	3065
Mean	1888	1767	1631	1023	969	598	5735	5624	5959	5365	4969	3083	4099	3811	2980
CD ($p = 0.05$)	285	349	316	198	192	75	799	914	695	1316	1039	472	539	567	326
SE (m)	98	120	148	68	65	26	274	348	238	451	356	161	185	194	112
CV (%)	10.4	13.6	12.4	13.3	13.6	8.6	9.6	12.3	8.0	16.8	14.3	10.5	9.0	10.2	7.5

MEY-Maize equivalent yield.

terms of maize equivalent yield (MEY) was significantly influenced by different inorganic and organic fertilizers alone or in combinations. The maximum MEY (4325 kg/ha) was obtained from treatment T_9 followed by MEY values of 4243 and 4051 kg/ha recorded with the treatments T_7 and T_6, respectively. That may be due to the fact that efficiency of inorganic fertilizers increased when these are used in conjunction with organic manures. The results are in line as reported by Yadav 2001. The MEY values in farmer's practice out yielded over T_5, T_3 and T_4 treatments by about 13, 14 and 18%, respectively on pooled data basis (Table 3). The organic sources enhanced the efficient utilization of the native as well as added fertilizer nutrients, which maintained balance between growth and yield attributes. Thus inclusion of organic sources at either of the level in *kharif* only enhanced the productivity of the system. The increase in yield of maize-gobhi sarson system was found in consistent with the findings of Abrol *et al.* (2007) and Panwar (2008).

Effect of N application through different sources on available N content and changes in available nitrogen content in experimental soils was studied (Fig. 1). Available nitrogen in soil increased where nitrogen was supplied through integrated approach *i.e.* organic + inorganic sources. The extent of increase in available N was highest (33 kg/ha) in treatment where 50% recommended nitrogen was supplied through inorganic source (urea) and rest of the 50% through organic source (FYM) followed by treatment where 50% recommended nitrogen was supplied through inorganic source (urea) and rest 50% through organic source (crop residue). The extent of increase in available N in this treatment was 26 kg/ha. In control as well as in treatments where N was supplied purely through inorganic sources a decrease in available nitrogen was noticed. The increase in available N in treatments where the N was supplied through integrated sources could be attributed to the production of carbonic acids during decomposition of organics which mineralize the complex organic substances which in turn contribute to the N pool. The increase could also be attributed to greater multiplication of soil microbes caused by the addition of organics which mineralize organically bound N to inorganic form. The results are in the conformity of the findings of Bellakki and Badanur 1997.



CON = Control (no nitrogen), RN = 100% recommended nitrogen (urea), FRN = 50% recommended nitrogen (urea), FNCR = 50% recommended nitrogen (urea) + 50% recommended nitrogen through crop residue, FNFYM = 50% recommended nitrogen (urea) + 50% recommended nitrogen through farm yard manure

Fig. 1. Change in soil available nitrogen by repeated applications of nitrogen through different sources.

Statistically highest rain water use efficiency (RWUE) values were recorded in T_9 treatment (3.38 kg/ha/mm) in maize crop which was followed by the values obtained in T_2 treatment (2.99 kg/ha/mm). However, the treatments where 50% N was replaced by FYM and crop residue (T_7 and T_6) along with 50% inorganic N observed statistically similar values of RWUE in maize crop.

Treatment T_8 registered statistically highest values of RWUE (6.07 kg/ha/mm) in gobi sarson crop. However, control recorded the least RWUE (1.68 and 3.37 kg/ha/mm) values both in maize and gobi sarson crops, respectively. Treatment T_7 recorded the highest (8.59 kg/ha/mm) RWUE values for maize-gobi sarson system and was followed by statistically similar value obtained in T_6 treatment (8.24 kg/ha/mm). The control evinced the lowest RWUE value (5.05 kg/ha/mm) for the system (Fig. 2).

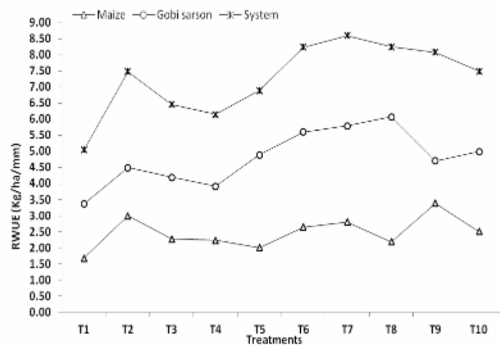


Fig. 2. Rain water use efficiency (RWUE) of maize, gobi sarson and system as affected by integrated nutrient management (mean of 3 years).

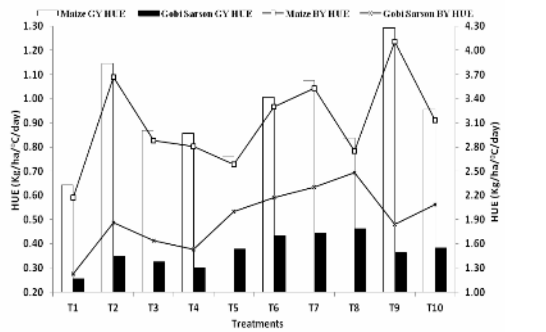


Fig. 3. Heat use efficiency (HUE) of grain and biological yield of maize and gobi sarson crops (pooled data) as affected by integrated nutrient management (mean of three years).

Statistically highest grain yield heat use efficiency (GYHUE) in maize was found to be 1.29 kg/ha/^{0}C/day found in treatment T_9, followed by statistically different GYHUE value 1.14 kg/ha/^{0}C/day found in T_2 treatment; however the treatment T_2 shared statistically same value of GYHUE (1.08 kg/ha/^{0}C/day) with treatment T_7 (Fig. 3). Maximum GYHUE value (0.46 kg/ha/^{0}C/day) in gobhi sarson crop was found in treatment T_8 followed by statistically at par value to the tune of 0.44 and 0.43 kg/ha/^{0}C/day in treatments T_7 and T_6, respectively. The biological yield heat use efficiency (BYHUE) of maize and gobhi sarson crops followed the similar trend. The various treatments of organic and inorganic nutrients significantly affected the dry matter accumulation in maize and gobhi sarson crops due to which significantly different values of GYHUE and BYHUE values of both the crops were obtained.

References

Abrol V, Sharma V, Sharma P, Khar D, Vittal KPR and KL Sharma 2007. Direct and residual effect of organic and inorganic sources of nutrients on maize (*Zea mays*)-mustard (*Brassica napus*) cropping sequence under rainfed conditions. Ind. J. Dry. Agric. Res. Devel. **22**: 82-89.

Anonymous 2010. Directorate of Economics and Statistics, Agricultural Statistics at Glance. Department of Agricultural and Cooperation. Ministry of Agriculture, Government of India.

Balakrishanan K and Natarajaratnam N 1986. Heat unit efficiency in pigeonpea. Mad. Agric. J. **73**: 101-104.

Bellakki MA and Badanur VP 1997. Long term effect of integrated nutrient management on properties of vertisols under dryland agriculture. J. Ind. Soc. Soil Sci. **45**: 438-442.

Gaur AC 1998. Integrated plant nutrient supply system blending organic, bio and chemical sources. (*In*): Soil-Plant-Microbe Interaction in relation to Integrated Nutrient Management. Kaushik BD (Ed), Division of Microbiology, Indian Agricultural Research Institute, New Delhi. pp. 14-27.

Jamwal JS 2005. Productivity and economics of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system under rainfed areas of Jammu. Ind. J. Agron. **50**: 110-112.

Kumar A, Thakur KS and Manuja S 2002. Effect of fertilizer levels on promising hybrid maize (*Zea mays*) under rainfed conditions of HP. Ind. J. Agron. **47**: 526-528.

Kumpawat BS 2004. Integrated nutrient management for maize (*Zea mays*)-Indian mustard (*Brassica juncea*) cropping system. Ind. J. Agron. **49**: 18-21.

Kumwenda JDT, Waddington SR, Snapp SS, Jones RB and Blackie MJ 1996. Soil fertility management research for the maize cropping systems of smallholders in Southern Africa: A review. NGR paper 96-102, Mexico, D F: CIMMYT.

Nuttonson MY 1955. Wheat-climate relationships and the use of phenology in ascertaining thermal and photothermal requirements of wheat. American Institute of crop Ecology, Washington DC, pp. 388.

Panwar AS 2008. Effect of integrated nutrient management in maize (*Zea mays*)-mustard (*Brassica compestris* var *toria)* cropping system in mid hills altitude. Ind. J. Agric. Sci. **78**: 27-31.

Pathak SK and Singh SN 2002. Effect of integrated nutrient management on growth, yield and economics in maize-wheat cropping system. Ind. J. Agron. **47**: 325-332.

Rao VUM, Singh D and Singh R 1999. Heat use efficiency of winter crops in Haryana. J. Agromet. **1**: 143-148.

Yadav RL 2001. On farm experiments on integrated nutrient management in rice-wheat cropping system. Experim. Agric. **37**: 99-113.

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