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Organic, integrated and chemical farming in wheat *(Triticum aestivum)* under maize *(Zea mays)*–wheat cropping system

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ABSTRACT

A field experiment with organic vs chemical farming with maize *(Zea mays* L.)–wheat *(Triticum aestivum* L. emend. Fiori & Paol.) system was initiated during 1996–97. On the same field, the investigation was expanded to organic (pure), integrated (partial) and chemical farming systems during winter seasons of 2001–02 and 2002–03 and was conducted at the experimental farm, Ludhiana, on sandy-loam irrigated soil. In maize–wheat sequence, on an average M_{20}-M_{20}-RI [FYM 20 tonnes/ha each to maize and wheat and incorporation of residues (RI)], M_{10}-M_{15}-GM, RI (GM-green manuring before maize), Rec.-GM-RI (Rec.-recommended chemical fertilizers) and Rec.-GM-R0 (R0-residue removed); pure and partial organic farming treatments gave 12.4, 8.3, 8.0 and 5.9% higher wheat grain yield than the Rec. treatment. M_{20}-M_{20}-RI and M_{10}-M_{15}-GM-RI (pure organic), Rec.-GM-RI and Rec.-GM-R0 (partial organic) treatments produced significantly higher plant height, dry-matter accumulation, leaf-area index, PARI (%), effective tillers/m^2, ear length, number of grains/ear and recorded higher root density and SPAD readings and also showed less canopy and soil temperature as compared to Rec. treatments.

Key words : Organic farming, Farmyard manure, Green manuring, Residue incorporation, Wheat

In the anxiety of increasing food production to meet the needs of ever-increasing population of the country, there had been excessive use of agrochemicals for the last 50 years, and least attention was given to ecological agriculture. Consequently, the danger signals have started coming sooner than expected. Many of our highly productive soils have started showing signs of declining productivity. The prolonged and over-use of chemicals than crop requirement resulted in human health hazards and imbalance in natural resources. In this context, a keen awareness has to be created on the adoption of organic farming as a remedy to maneuver the ill-effects from chemical farming. The total nutritional consumption (NPK) from chemical fertilizers is about 17.85 million tonnes (Pathak *et al.,* 2002) in India. To substitute the same, enough organic sources like dung, crop residues etc. are available with us. Thus, organic farming has a good potential under Indian context and this approach will conserve natural resources also. Therefore, an experiment was conducted to study performance of wheat with different organic and inorganic sources of nutrition in terms of growth and development, yield attributes and yield.

MATERIALS AND METHODS

The experiment was conducted during the winter (*rabi*) seasons of 2001–02 and 2002–03 at Department of Agronomy and Agrometeorology, Punjab Agricultural University, Ludhiana (on already in progress experiment since rainy season 1996). The soil of experimental field was loamy sand (Typic Ustochrept), medium in organic carbon content (0.48 %), low in N (145 kg/ha), high in P (27 kg/ha) and in K (116 kg/ha) status. The experiment was arranged in randomized block design with 4 replications comprising 8 treatments (Table 1). The treatments consisted of 2 farming systems, i.e. organic and chemical farming, and 4 nutrient supply systems. In the chemical farming system for raising wheat, 125 kg N/ha, 62.5 kg P_2O_5/ha and 30 kg K_2O/ha, i.e. recommended level of fertilizer (Rec.) with or without green manuring (GM) to rainy season crop/with (RI) or without (R0) residue incorporation, Rec.-GM-RI or Rec.-GM-R0 or 25% more N than recommended were added. Nitrogen was applied through urea, P_2O_5 through single superphosphate and K_2O through muriate of potash, while in organic farming well-rotten farmyard manure was applied on air-dry weight basis at 20 tonnes/ha each to maize (M_{20}) and wheat (M_{20}) along with crop residues incorporation (M_{20}-M_{20}-RI) for first 5 years. Later on, the quantity of FYM was reduced to 10 tonnes/ha (M_{10}) to maize along with green manuring [with and without (RI and R0) crop residues incorporation] and 15 tonnes FYM/ha (M_{15}) to wheat (with and without crop residues incorporation) (M_{10}-M_{15}-

GM-RI, M_{10}-M_{15}-RI, M_{10}-M_{15}-R0). Composition of FYM indicated 57.3–60.8% moisture, 0.68–0.75% N, 0.34–0.40% P, 0.71–0.75% K, 56–61 ppm Zn, 14–17 ppm Cu, 475–485 ppm Fe and 161–166 ppm Mn, while the respective figures for green manure were 81.5–82.3, 2.15–2.20, 0.13–0.15, 1.52–1.56, 31–33, 13–14, 291–293 and 647–652 for both the years on dry-weight basis. Green manuring of sunnhemp (*Crotalaria juncea* L.) 45 days old (17–20 tonnes/ha) 5–7 days before sowing maize was done. Crop residues were incorporated at harvest as per treatments. The sowing of wheat ('PBW 343') was done on 8 November 2001 and 3 November 2002 using 100 kg seed/ha. For wheat, 4 irrigations during first year and 3 irrigations during second year were applied. Weeds were controlled mechanically in organic farming, while in chemical farming, grassy weeds were controlled with the application of puma super 10 EC (Fenoxaprop-p-ethyl) @ 100 g a.i./ha 30–35 days after sowing. For controlling broad-leaf weeds a follow-up application of 2, 4-D was made @ 0.5 kg/ha at maximum tillering stage.

For wheat crop, the plant height and dry matter accumulation were taken at maturity. Leaf area of plants was recorded 120 days after sowing and expressed as leaf-area index (LAI). The number of effective and non-effective tillers was recorded after heading, while the ear length excluding awns and number of grains/ear at maturity. The SPAD readings (chlorophyll content) were taken at heading stage with SPAD meter. After threshing, grain yield was recorded. For the canopy air temperature, data were recorded from dry bulb readings of an Assman Psychrometer and soil temperature (°C) was recorded at 5 cm soil depth with a bimetal soil thermometer between 9.00 AM to 10.00 AM, and 2.00 PM to 3.00 PM. Penetration of PAR (nm) was measured between 9.00 AM to 10.00 AM, 12.00 noon to 1.00 PM and 3.00 PM to 4.00 PM with photometer as the quantum (photon) response through wavelength range of 400–700 nm for PPFD (photosynthetic photon flux density). The data were used for calculating the photosynthetically active radiation interception (PARI) by crop as :

$$\text{PARI}(\%) = \frac{\text{PAR above the crop canopy} - \text{PAR at soil surface}}{\text{PAR above the crop canopy}} \times 100$$

For root density, dry root weight was recorded as per standard procedures. By dividing dry weight with volume of the core sampler, root density was calculated and expressed as $\mu g/cm^3$.

RESULTS AND DISCUSSION

Plant height

Plant height recorded at the time of harvest in Rec. treatment was found to be significantly low as compared to all other treatments. More plant height in fully or partial organically raised wheat crop may be due to synchronized availability of essential plant nutrients to the crop for a longer period during its growing stage.

Dry matter accumulation

At harvesting, M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, Rec.-GM-RI and Rec.-GM-R0 treatments resulted in significantly more dry matter. More dry matter accumulation in the pure or partial organic treatments may be due to more plant height, more leaf area and due to more tillers (Table 1). Similar observations were also recorded by Brar (2003).

Leaf-area index (LAI)

Leaf-area index of wheat crop revealed that all the tried treatments (except Rec. + 25% N) recorded significantly more leaf-area index than the crop raised with chemical farming treatment (Rec.). More leaf-area index in pure/partial organic treatments may be due to more plant height, more dry matter accumulation and due to more number of tillers (Table 1) as compared to purely chemical fertilized crop. Such observation were also recorded earlier by Brar (2003).

Tillers

The number of effective tillers per unit area was significantly higher in M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, M_{10}-M_{15}-RI, Rec.-GM-RI and Rec.-GM-R0 treatments as compared to Rec. treatment. Non-effective (no ear bearing) tillers were significantly less in M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, M_{10}-M_{15}-RI and M_{10}-M_{15}-R0 treatments as compared to the crop raised with recommended levels of chemical fertilizers. Higher number of tillers in pure or partial organic treatments may be due to better growth and development of wheat indicated by more periodic height, more periodic dry matter accumulation, more leaf- area index (Table 1) and improvement in soil physico-chemical properties due to addition of manures.

Root density

The root density data (Table 1) showed that more than 70% roots were confined to the top (0–15 cm) soil layer. The fully or partial organic treatments resulted in higher rooting density. The M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, Rec.-GM-RI and Rec.-GM-R0 recorded 22.4, 19.9, 19.3 and 15.6% higher root density than Rec. treatment in 0–15 cm soil layer and respective values were 21.4, 18.2, 18.8 and 13.0 in 15–30 cm soil layer and 13.1, 13.1, 10.3 and 4.7 in 30–60 cm soil layer. The lower layer, i.e. 60–90 and 90–120 cm, recorded less density. The more root mass might be due to beneficial effect of FYM on soil structure, which in turn increased the infiltration and retention of water, improved soil aeration, root penetration and moderated soil temperature.

PARI

The data on PARI (%) by different treatments (Table 2) indicated that 120 days after sowing stage, M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, M_{10}-M_{15}-RI, Rec.-GM-RI and Rec.-GM-R0 intercepted significantly higher amount of solar radiation compared with crop supplied with recommended chemical fertilizers (Rec.) This may be due to active growth of crop as is evident from number of tillers/unit area and more leaf-area index (Table 1), which resulted in thick crop canopy and thus, intercepted more solar radiation. Similarly, Dhaliwal and Kler (1995) reported that leaf-area index increased as crop advanced in age, capturing more light in total as well as upper half of the canopy profile.

Soil temperature

Soil temperature (ºC) beneath the crop canopy values (Table 2) showed that the fully or partial organic farming treatments tended to have lower soil temperature. This may be due to more tillers/unit area and more leaf-area index (Table 1). Moreover, where light was intercepted more, it penetrated less to ground resulting in lower soil temperature. Thus, higher PARI % caused lower temperature (Dhaliwal and Kler 1995).

Canopy temperature

The periodic canopy temperature (ºC) values (Table 2) showed that the fully or partial organic treatments, i.e. M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, M_{10}-M_{15}-RI, M_{10}-M_{15}-R0, Rec.-GM-RI and Rec.-GM-R0 recorded slightly less canopy temperature than the Rec. treatments (Rec. and Rec. + 25% N). This may be attributed to more tillers/unit area and more leaf-area index (Table 1), resulting in higher PARI % and lower soil temperature as reported by Dhaliwal and Kler (1995).

Ear length

The ear length (Table 3) was significantly more in the M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI, Rec.-GM-RI and Rec.-GM-R0 treatments as compared with alone chemical fertilizer (Rec.) treatment. The ear length might have increased with continuous supply of photosynthates to the sink due to slow release of nutrients from organic source.

Table 1. Effect of organic and chemical farming treatments of growth parameters and root density of wheat in maize–wheat system (pooled 2 years)

Treatment	Plant height (cm)	Dry matter accumulation (q/ha)	LAI 120 DAS	Effective tillers/m²	Non-effective tillers/m²	Root density (μg/cm³) 0–15	15–30	30–60	60–90	90–120
M_{20}-M_{20}-RI	96.8	128.1	2.3	435.0	15.0	2,310	323	121	97	76
M_{10}-M_{15}-GM-RI	95.8	123.2	2.2	424.0	16.0	2,263	315	121	92	75
M_{10}-M_{15}-RI	93.6	119.3	2.2	401.0	17.0	2,056	281	111	91	73
M_{10}-M_{15}-R0	91.8	116.5	2.1	389.0	19.5	1,942	272	112	93	74
Rec.-GM-RI	95.0	123.1	2.2	424.0	21.5	2,252	316	118	96	76
Rec.-GM-R0	93.9	120.4	2.1	421.0	21.5	2,181	301	112	96	75
Rec. + 25% N	91.7	118.4	1.9	396.0	23.0	1,761	278	113	94	73
Rec.	88.5	114.0	1.8	389.0	23.5	1,887	266	107	96	73
CD (P=0.05)	2.6	5.7	0.2	11.0	2.9					

Table 2. Effect of organic and chemical farming treatments on micro-climatic observations of wheat (120 DAS) in maize–wheat system

Treatment	PARI (%)		Soil temperature (ºC)		Canopy temperature (ºC)	
	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03
M_{20}-M_{20}-RI	89.4	87.9	24.0	22.1	26.2	25.4
M_{10}-M_{15}-GM-RI	88.0	87.2	24.5	22.3	26.8	25.6
M_{10}-M_{15}-RI	86.7	85.6	25.0	22.6	27.0	26.1
M_{10}-M_{15}-R0	83.3	84.3	25.5	22.8	27.4	26.3
Rec.-GM-RI	87.8	86.5	24.6	22.3	26.3	25.5
Rec.-GM-R0	86.3	85.8	25.2	22.8	26.5	25.6
Rec. + 25% N	82.0	83.2	25.4	23.6	27.1	26.4
Rec.	80.3	82.0	26.1	23.6	27.3	26.6
CD (P=0.05)	5.6	3.5				

Table 3. Effect of organic and chemical farming treatments on ear length, grains/ear, SPAD readings, grain and straw yields of wheat in maize–wheat sequence (pooled 2 years)

Treatment	Ear length (cm)	Number of grains/ear	SPAD readings (chlorophyll content)	Grain yield (q/ha)	Straw yield (q/ha)
M_{20}-M_{20}-RI	11.0	41.8	42.7	57.9	70.2
M_{10}-M_{15}-GM-RI	10.5	41.2	42.4	55.8	67.4
M_{10}-M_{15}-RI	9.9	38.2	41.8	54.2	65.1
M_{10}-M_{15}-R0	9.4	36.8	40.4	52.6	63.8
Rec.-GM-RI	10.8	41.0	41.9	55.7	67.4
Rec.-GM-R0	10.2	40.8	41.1	54.6	65.8
Rec. + 25% N	9.8	38.1	39.2	54.0	64.4
Rec.	9.2	36.7	37.4	51.5	62.5
CD (P=0.05)	0.9	3.9		3.0	3.8

Grains/ear

Number of grains was significantly more in the pure or partial organic treatments (Table 3). Favourable effect of FYM application on plant growth parameters might have enhanced number of grains/ear, which increased photosynthate supply to the ear. Nehra *et al.* (2001) also reported the similar results.

Chlorophyll content

SPAD reading (chlorophyll concentration) was estimated at heading stage from the flag leaf. The fully or partial organic farming treatments showed higher SPAD readings (chlorophyll content) than alone chemical fertilizer (Rec.) treatments. The higher chlorophyll content may be due to more availability and uptake of plant nutrients.

Grain yield

The highest grain yield (Table 3) was obtained in M_{20}-M_{20}-RI treatment which was followed by M_{10}-M_{15}-GM-RI, Rec.-GM-RI and Rec.-GM-R0 treatments and these treatments resulted in significantly higher grain yield than the crop receiving only the recommended dose of chemical fertilizers (Rec.). These treatments increased grain yield by 12.4, 8.3, 8.0 and 5.9%, respectively, than Rec. treatment owing to positive influence of balanced source-sink relationship as evident from remarkable improvement in plant height, dry matter accumulation, leaf-area index, total and effective tillers, PARI (%), root growth (Table 1), ear length, grains/ear, chlorophyll content (Table 3). All sources of organic manures improved the yield, quality and soil fertility (Hemalatha *et al.*, 2000). The green manuring done before maize also showed their residual beneficial effect on grain yield of succeeding wheat (Bhandari *et al.*, 2000).

Straw yield

Lowest straw yield was recorded in the treatment receiving chemical fertilizers alone. However, the M_{20}-M_{20}-RI, M_{10}-M_{15}-GM-RI and Rec.-GM-RI treatments gave significantly more straw yield as compared to chemical fertilizer (Rec.) treatment. Increase in straw yield with fully or partly organic farming treatments could be due to dry matter production in vegetative parts and increased morphological parameters of growth, i.e. plant height, dry mater, LAI and number of tillers (Table 1).

The results of the present study which was initiated 7 years before indicated that organic farming with the application of farmyard manure, green manure and incorporation of crop residues proved beneficial in boosting the crop yields in comparison to alone chemical fertilizers. Wheat grain yield was increased by 12.4% in maize–wheat system.

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