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ORIGINAL ARTICLE

Impact of Nitrogen, Irrigation and sub surface application of Manure on Wheat productivity

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ABSTRACT
Application of manures as a surface incorporation significantly affects the soil properties and crop productivity. However, its impacts through sub surface application along with variable irrigation and nitrogen regimes are not known. To test this hypothesis two field experiment were conducted at the Research Farm, Department of Soil Science, Punjab Agricultural University, Ludhiana in a sandy loam soil. The study included three treatments i.e. surface application (SA) of manure, sub surface application (SSA) of manure and control (C) i.e. without FYM application, along with two irrigation regimes i.e. (IW/PAN-E 0.6 and 0.9) i.e. I1 and I2 in one experiment and two N levels i.e. 90 kg N ha^{-1} (N1) and 120 kg N ha^{-1} (N2) in second experiment. The SSA practice produced higher wheat grain yield (5.7 t ha^{-1} and 5.6 t ha^{-1}) followed by SA (5.5 t ha-1and 5.3 t ha^{-1}) and minimum in C (5.4 t ha^{-1} and 5.2 t ha^{-1}) at I2 and N2, respectively. The plant height, number of tillers and biomass yield were also found to be higher under SSA followed by SA and minimum in C at maximum irrigation and nitrogen regimes. Thousand grain weight (TGW) of wheat was observed to be maximum in SSA (34.7 g and 34.2 g) followed by SA (33.4 g and 33.2 g) and least in C (32.6 g and 32.1 g) at I2 and N2 levels, respectively. Among irrigation regimes, higher wheat grain yields were recorded at IW/PAN-E 0.9 (5.5 t ha^{-1}) level than IW/PAN-E 0.6 (5.3 t ha^{-1}). Irrigation water productivity (IWP, kg ha^{-1} mm^{-1}) was also significantly influenced by manure application mode, maximum IWP was recorded at SSA followed by SA and lowest under C. The sub surface application of manure had also effect on mean soil bulk density with highest values under C (1.61 Mg m^{-3}) and lowest under SSA (1.57 Mg m^{-3}). Similarly, infiltration rate (IR) of soil was also affected by manure application mode, where maximum mean final IR was recorded under SSA (1.4 cm hr^{-1}) followed by SA (1.2 cm hr^{-1}) and least in C (1.1 cm hr^{-1}). The mean water holding capacity, water stable aggregates and porosity were also found to be higher under SSA than control and SA treatments. It may be concluded that sub surface application of manure has positive effect on soil properties and wheat productivity.
Key words: sub surface, manure, wheat, yield, water productivity, nitrogen

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INTRODUCTION

Application of organic manure improves the water infiltration, water retention, soil water contents, grain yield and water use efficiency. It plays an important role in improving soil physical conditions through better water and nutrient uptake and greater penetration and establishment of rooting system. The better roots help the plant to utilize water from deeper layers and to maintain higher relative plant water content under a soil moisture stress condition in limited water supply areas. Manure application improved wheat growth and productivity compared to the un-amended control; the response was dependent on the mode of application. The application of organic manures through surface incorporation may not bring a sustainable increase in yields. However, its sub surface application may enhance crop and water productivity. The research efforts on how to apply farmyard manure (FYM) together with chemical fertilizers could be one alternative solution for sustainable wheat productivity and better soil environment. The soil mechanical and water transmission properties along with crop productivity were reported to be improved under manure application. Depending on the frequency and distribution of the rain and soil texture, wheat crop need four or five irrigations [1]. The conventional practices of cultivating crops like intensive tillage without manure and crop residue management and improper use of irrigation water negatively affect the soil health, crop yield and environment conditions by affecting soil carbon loss, soil structure, and emission of greenhouse gases [1]. There are also chances of hard pan formation at subsurface soil depth particularly where rice-wheat cropping system is practiced for several decades. This hard pan restricts the root proliferation and also affects the water transmission characteristics of soil. As a solution to solve this problem, sub surface application of manure is the alternate practice. Sub surface application (SSA) may influence water use efficiency and profile water usage. The SSA can store more of the rainfall water. An appropriate manure application along with irrigation and nitrogen levels can improve water availability to the crops by increasing soil moisture storage, reducing soil evaporation and allowing a better development of root system. Root system acts as a bridge between the impacts of agricultural management on soil and changes in shoot function and harvested "yield [10]. Under water stressed condition, the deep root system helps the crop to extract water from deeper soil layers. Due to better root proliferation under SSA, the crop water productivity can be increased. The SSA has only modest influences on seepage and percolation rates. Farmers, therefore need to manage their resources and adopt appropriate manure application practices without removing residues in order to effectively store and use the water input efficiently for crop production. Manure and irrigation are the most influential soil manipulations having short-term effects on soil physical and hydraulic properties, which influence the fate of water applied to the soil. The relationship between manure and irrigation regimes has always been a complex one. Irrigation levels are well known to affect crop performance. Therefore, irrigation management needs an appropriate crop monitoring taking into account the water requirements of plants and soil. The various physical properties of soil such as bulk density, porosity and water holding capacity are fundamental indicators that show the effect of manure application on soils hydraulic properties. Subsoil compaction hinders the uptake of water and plant nutrients from deeper layers, thereby resulting in lower crop yields. To overcome subsoil compaction, remediation management practices were SSA and selection of crops with deep root system. The SSA cracks up the high-density soil layer, increase infiltration and movement of water in the soil, improves root growth and development and hence increase the production potential of crop. The water stress is more acute on the highly permeable coarse textured soils having low water retention capacity. Poorly developed root system of the crops due to the subsoil compaction having high soil strength [7] further aggravates the problem by restricting the size of the exploitable water reservoir. Management practices to overcome these problems include the measure that promote the rooting volume of soil, improve the water supply, and regulates the soil thermal as well as hydraulic regimes.

MATERIAL AND METHODS

The field experiments were conducted at research farm of Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab, India situated at 30°54' N latitude, 75°58' E longitude at an altitude of 247 m above the mean sea level. The experimental area is designated with a subtropical and semi-arid climate, with hot and dry summers (April-June), wet monsoon (late June-mid September) and a cool dry winter (October-February) season. The mean minimum and maximum temperature show considerable fluctuation during summer and winter months. The average annual rainfall range is 650-700 mm about 75 percent of which is received by south-western monsoon in the month of July to September and light showers are received in the month of December-January by north-western monsoon. The depth of ground water in the region is around 24 m with a good. The study included three manure application modes i.e. surface application (SA), sub surface application (SSA) and control (C i.e. without FYM application) along with two irrigation regimes i.e. (IW/PAN-E 0.6 and 0.9) i.e. I1 and I2, respectively in one experiment and two N levels i.e. 90 kg N ha^{-1} (N1) and 120 kg N ha^{-1} (N2) in second experiment. The experiment was replicated thrice. Ten plants per plot were randomly selected and their height was measured from ground surface to the tip of the plant at 120 DAS. The values were then averaged to single plant. The tiller density was determined by counting the number of tiller per square meter. The crop biomass was determined at 120 DAS and the above ground parts of the plants were dried and weighed from net area per plot. Grain yield and biomass were recorded in kg from 10 m^2 area per plot and presented in t ha^{-1}. One thousand grains per plot were manually counted and weighed precisely and presented in grams. Irrigation water productivity was calculated by dividing the grain yield with amount of irrigation water applied.

The undisturbed soil was taken in cores having 7.5 cm height and 8.0 cm inner diameter. The soil from the core was oven dried at 105 °C until the soil weight reaches a constant value. Bulk density (ρ_b) is expressed as the ratio of mass of dry soil (M_s) and internal volume (V_t) of the cylindrical core i.e. volume of soil [4].

Bulk density (ρ_b) = M_s/V_t

Porosity of soil was determined as the ratio of bulk density to particle density subtracted from one. The wet sieving method [21] was used to determine the aggregation status of soil. Soil peds were air dried and sieved through 8 mm sieve and those peds that collected over the 4 mm sieve were selected. Yoder's wet sieving apparatus, consisting of four sieve sets, each with five sieves (12.7 cm wide and 5 cm high) ,with holes of 2.0, 1.0, 0.5, 0.25 and 0.1 mm size was used. The soil peds were distributed evenly over the topmost sieve of the set and moistened by capillarity for around 10 minutes. Then the sieve set was agitated for 30 minutes. After that, the sieves were dried in an oven at 105 °C till the constant weight was obtained. The soil mass retained on each sieve was oven-dried and weighed. The water stable aggregates (WSA) [11] were determined by the formula below:

$$\text{WSA} > 0.25\ \text{mm}(\%) = \frac{\sum_{i=1}^{n} w_i}{\text{weight of soil peds}} \times 100$$

Where, n is number of size fractions, d_i is the average diameter for each size range, w_i is the weight of aggregates in a particular size range as a ratio of the total dry weight of the soil peds taken.

In-situ measurement of infiltration was done using double ring infiltrometer method by Reynolds *et al* [16]. First, the water was filled in the outer ring followed by the inner ring upto the same level and the lowering of the level of water in the inner ring was measured using installed meter scales inside the inner ring at various periods of time until the rate of water intake in soil reaches a stable value. Water holding capacity was calculated using keen's box method. The data was statistically analyzed in statistical package CPCS-I according to Cochran and Cox [6] (and adapted by Cheema and Singh [5]) and it was compared at significance level of 5%.

RESULTS AND DISCUSSION

Plant height and number of tillers: Plant height is a dependable plant growth index at any stage during the growth period. It is frequently used to evaluate the effect of particular treatments on crop growth because plant height (inspite of being a genetic character), can be influenced by manure application or other management interventions. The data pertaining to the impact of mode of manure application, N levels and irrigation regimes on wheat plant height is presented in Tables 1 and 2. Maximum plant height (cm) was observed under SSA (90.7 and 89.7) followed by SA (89.4 and 88.3) and lowest in case of C (88.6 and 87.2) at full irrigation and nitrogen regimes, respectively. Higher plant height under SSA in comparison to C might be due to greater moisture and nutrient availability owing to deeper rooting under SSA. Higher N applications increase the cell division, cell elongation, number and length of internodes, maintains higher auxin and protein level in plants and therefore encourages the shoot growth. Also, higher N levels increased the chlorophyll content which increased the photosynthetic rate and plant height. Increased plant height with the increase of N levels has also been observed by Imran *et al* [9]. In general, plant height increased with increase in the frequency of irrigations. Bandyopadhyay [3] also reported significant influence of irrigation levels on plant height. The effect of irrigation regimes and nitrogen levels on tiller density of wheat have been presented in Table 1 and 2. The mean tiller density was observed to be higher under SSA (423.6 and 415.6 tillers m^{-2}) than SA (414.4 and 410.2 tillers m^{-2}) at full irrigation and nitrogen regimes. However, minimum tiller density was recorded in C i.e. 408.5 and 405.5 tillers m^{-2} at I2 and N2 levels. Again among irrigation regimes higher mean tiller density was recorded at I2 (415.5 tillers m^{-2}) than I1 (410.3 tillers m^{-2}). This could be due to the similar reason i.e. under I1 tiller mortality was more due to water stressed conditions. The higher tiller density under SSA conditions could be due to improved physical condition of the soil.

Thousand grain weight (TGW)

The data presented in Tables 3 and 4 represents the effect of mode of manure application, N levels and irrigation regimes on thousand grain weight (TGW) of wheat. The maximum TGW (g) was recorded under SSA (34.7 and 34.2) followed by SA (33.4 and 33.2) and least under C (32.6 and 32.1) at maximum irrigation and nitrogen regimes, respectively. The TGW increased with increase in N levels. Maximum mean TGW was observed at N2 (33.2) which was significantly higher than that at N1 (31.6). These results are in full agreement with those observed by Hokamlipour *et al* [8] and Radma and Dagash [15]. This might be attributed to proper physiological functioning of N in tissue development, cell division, enhanced plant growth and thereby increased TGW. Low N supply decreases maize TGW due to decreased supply of carbohydrates and amino compounds to the grain as reported by Paponov *et al* [20]. Irrigation regimes also show impact on TGW. Among irrigation regimes higher mean TGW was recorded at I2 (33.6 g) than I1 (32.3 g). The higher TGW under SSA conditions could be due to improved physical condition of the soil and better plant growth.

Crop biomass

The crop biomass represents the collective effect of vegetative growth and plant parameters and depicts the overall crop performance. The data relating to effect of manure application mode, N levels and irrigation regimes on wheat biomass is presented in Tables 3 and 4. Maximum wheat biomass (t ha^{-1}) was recorded under SSA (9.3 and 9.1) followed by SA (8.8 and 8.6) and minimum in C (8.6 and 8.3) at I2 and N2, respectively. Among irrigation regimes higher crop biomass was observed in I2 (8.9 t ha^{-1}) than I1 (8.0 t ha^{-1}). Similarly higher crop biomass was recorded at higher N level i.e. N2 (8.7 t ha^{-1}) as compared to N1 (8.2 t ha^{-1}). The reason for higher value of plant biomass under SSA could be improved soil physical environment and reduced soil mechanical resistance to root penetration, because aboveground biomass of plants is enhanced by a well-developed root system. More biomass under SSA might also be ascribed to taller plants and greater dry matter production. The increment in N levels lead to greater biomass accumulation, owing to greater photosynthesis, contributed by higher leaf area and greater N uptake resulting in the accumulation of significantly higher dry matter. Similar results were also reported by Kousar *et al* [19] and Almodares *et al* [2]. The results generally indicated a decline in efficiency of N use for grain yield by increasing N level. Similar results were also reported by Parija [13] observed the positive effect of higher N levels on crop biomass.

Grain yield and irrigation water productivity

The Tables 5 and 6 illustrate the effect of mode of manure application, N and irrigation levels on wheat grain yield. The maximum wheat grain yield (t ha^{-1}) was observed under SSA (5.7 and 5.6) followed by SA (5.5 and 5.3) and minimum in C (5.4 and 5.2) at I2 and N2 levels, respectively. Among irrigation regimes higher grain yield was observed in I2 (5.5 t ha^{-1}) than I1 (5.3 t ha^{-1}). Similarly higher grain yield was recorded at higher N level i.e. N2 (5.4 t ha^{-1}) as compared to N1 (5.1 t ha^{-1}). The reason behind higher yield under SSA was improved root proliferation in deeper layers and greater water and nutrient uptake. Rajkumara *et al* [14] also observed maximum grain yield under adequately irrigated soils. Singh *et al* [17] reported higher grain yield at IW/CPE 0.9 (5.0 t ha^{-1}) ratio than that at 0.6 (4.5 t ha^{-1}). Grain yield of wheat is a function of yield attributes, which are favourably influenced by N application. The grain yield significantly increased with increase in N levels. Higher yield with increase in N doses was due to higher dry matter accumulation. It was also reported by Ullah *et al* [18]. There was a strong synergistic effect of irrigation and N on grain yields. Better root growth and better moisture extraction under SSA helped the crop to first develop adequate source (as reflected by high above-ground biomass accumulation) and then development of better sink size and capacity (higher grain mass as compared to C. The higher yield with increase in N doses could be supported probably by increased chlorophyll content due to N being an important constituent of chlorophyll. Mode of manure application, N levels and irrigation regimes had a significant effect on irrigation water productivity (IWP) of wheat. Maximum IWP was recorded in SSA (17.4 and 14.7 kg ha^{-1} mm^{-1}) followed by SA (17.1 and 13.9 kg ha^{-1} mm^{-1}) and minimum in C (16.5 and 13.7 kg ha^{-1} mm^{-1}) at I1 and N2 levels, respectively. Among irrigation regimes higher IWP was observed in I1 (17.0 kg ha^{-1} mm^{-1}) than I2 (14.6 kg ha^{-1} mm^{-1}). But with the increase in N level IWP also increases and higher IWP was recorded at N2 (14.1 kg ha^{-1} mm^{-1}) as compared to N1 (13.3 kg ha^{-1} mm^{-1}). IWP decreased with increase in irrigation level. Mojid *et al* [12] also observed reduction in IWP with increasing level of irrigation.

Soil physical properties

The data relating to the effect of manure application mode on soil physical characteristics i.e. bulk density, infiltration rate and water holding capacity is presented in Fig 1. The maximum value of final IR (cm hr^{-1}) was reported under SSA (1.4 cm hr^{-1}) followed by SA (1.2 cm hr^{-1}), while C had the lowest value (1.1 cm hr^{-1}). However, maximum soil bulk density was observed in C (1.61 Mg m^{-3}) followed by SA (1.59 Mg m^{-3}) and minimum in SSA (1.57 Mg m^{-3}). Water holding capacity was observed to be maximum in SSA (45.0 %) followed by SA (44.5 %) and minimum in C (43.8 %). The data pertaining to effect of manure application mode on soil porosity and water stable aggregates is presented in Fig 2. Maximum soil porosity and water stable aggregates were observed in SSA (40.7 % and 56 %) followed by SA (40 % and 54 %) and minimum in C (39.2 % and 53 %), respectively.

Table 1: Effect of sub surface application of manure on wheat plant height (cm) and number of tillers (per m²) at two irrigation regimes

Tillage practices	Plant height (cm)		Number of tillers (per m²)	
	Irrigation regimes			
	IW/PAN-E=0.6	IW/PAN-E=0.9	IW/PAN-E=0.6	IW/PAN-E=0.9
SA	87.8	89.4	409.4	414.4
SSA	88.6	90.7	415.7	423.6
Control	87.1	88.6	405.8	408.5
Mean	87.8	89.6	410.3	415.5
LSD (,0.05)	Application mode = 0.8; Irrigation = 1.4 Interaction = NS		Application mode = 6.2; Irrigation = 4.9 ; Interaction = NS	

SA= surface application; SSA = sub surface application

Table 2: Effect of sub surface application of manure on wheat plant height (cm) and number of tillers (per m²) at two nitrogen levels

Tillage practices	Plant height (cm)		Number of tillers (per m²)	
	Nitrogen levels			
	90 kg N ha^{-1}	120 kg N ha^{-1}	90 kg N ha^{-1}	120 kg N ha^{-1}
SA	86.3	88.3.	388.8	410.2
SSA	87.7	89.7	395.7	415.6
Control	85.8	87.2	385.6	405.5
Mean	86.6	88.5	390.0	410.4
LSD (,0.05)	Application mode = 0.6; Nitrogen = 1.7 Interaction = NS		Application mode = 7.4; Nitrogen= 8.6 ; Interaction = NS	

SA= surface application; SSA = sub surface application

Table 3: Effect of sub surface application of manure on wheat thousand grain weight (g) and crop biomass (t ha-1) at two irrigation levels

Tillage practices	Thousand grain weight (g)		Crop biomass (t ha^{-1})	
	Irrigation regimes			
	IW/PAN-E=0.6	IW/PAN-E=0.9	IW/PAN-E=0.6	IW/PAN-E=0.9
SA	32.3	33.4	8.1	8.8
SSA	33.1	34.7	8.2	9.3
Control	31.4	32.6	7.8	8.6
Mean	32.3	33.6	8.0	8.9
LSD (,0.05)	Application mode = 0.7; Irrigation = 1.3 Interaction = NS		Application mode = 0.4; Irrigation = 0.7; Interaction = NS	

SA= surface application; SSA = sub surface application

Table 4: Effect of sub surface application of manure on wheat thousand grain weight (g) and crop biomass (t ha-1) at two nitrogen levels

Tillage practices	Thousand grain weight (g)		Crop biomass (t ha^{-1})	
	Nitrogen levels			
	90 kg N ha^{-1}	120 kg N ha^{-1}	90 kg N ha^{-1}	120 kg N ha^{-1}
SA	31.6	33.2	8.2	8.6
SSA	32.7	34.2	8.5	9.1
Control	30.5	32.1	7.9	8.3
Mean	31.6	33.2	8.2	8.7
LSD (,0.05)	Application mode = 0.8; Nitrogen = 1.5 Interaction = NS		Application mode = 0.5; Nitrogen = 0.5 ; Interaction = NS	

SA= surface application; SSA = sub surface application

Table 5: Effect of sub surface application of manure on wheat yield (t ha-1) and irrigation water productivity (kg ha-1 mm-1) at two irrigation levels

Tillage practices	Grain yield (t ha-1)		Irrigation water productivity (kg ha-1 mm-1)	
	Irrigation regimes			
	IW/PAN-E=0.6	IW/PAN-E=0.9	IW/PAN-E=0.6	IW/PAN-E=0.9
SA	5.3	5.5	17.1	14.5
SSA	5.4	5.7	17.4	15.0
Control	5.1	5.4	16.5	14.2
Mean	5.3	5.5	17.0	14.6
LSD (,0.05)	Application mode = 0.3; Irrigation = 0.2 Interaction = NS		Application mode = 0.8; Irrigation = 1.9 ; Interaction = NS	

SA= surface application; SSA = sub surface application

Table 6: Effect of sub surface application of manure on wheat yield (t ha-1) and irrigation water productivity (kg ha-1 mm-1) at two nitrogen levels

Tillage practices	Grain yield (t ha-1)		Irrigation water productivity (kg ha-1 mm-1)	
	Nitrogen levels			
	90 kg N ha-1	120 kg N ha-1	90 kg N ha-1	120 kg N ha-1
SA	5.0	5.3	13.2	13.9
SSA	5.3	5.6	13.9	14.7
Control	4.9	5.2	12.9	13.7
Mean	5.1	5.4	13.3	14.1
LSD (,0.05)	Application mode = 0.2; Nitrogen = 0.2 Interaction = NS		Application mode = 0.6; Nitrogen = 0.6 ; Interaction = NS	

SA= surface application; SSA = sub surface application

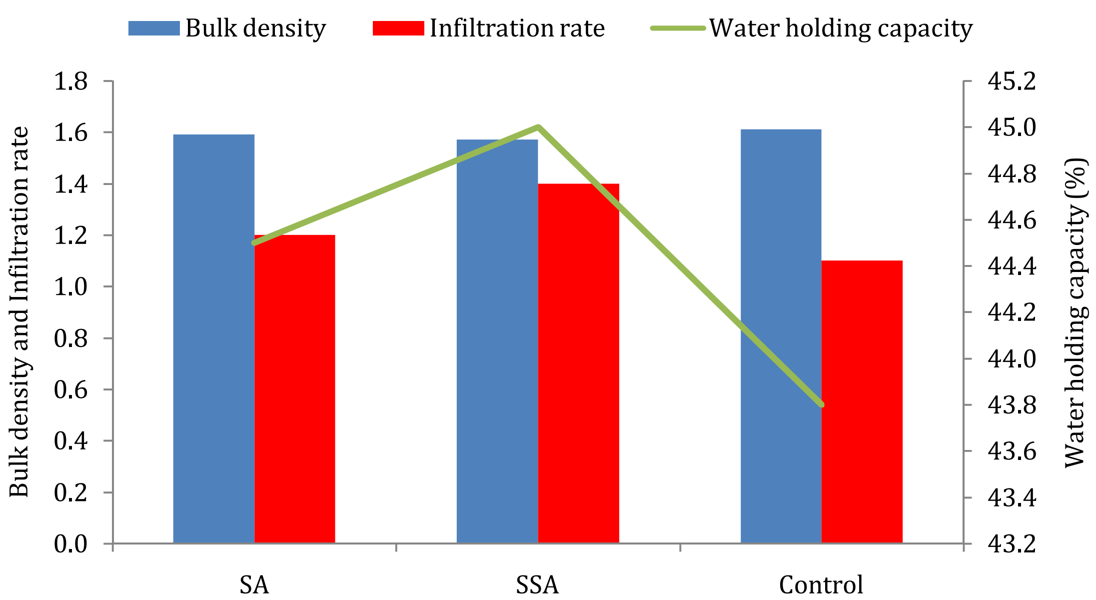

Fig 1: Effect of mode of application of manure on mean soil bulk density (Mg m-3), infiltration rate (cm hr-1) and water holding capacity (%)

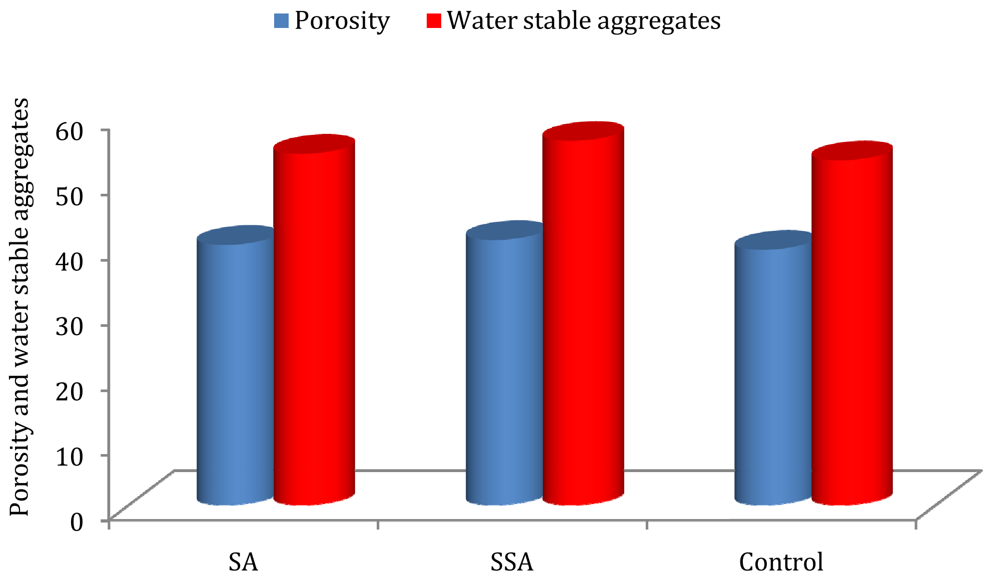

Fig 2: Effect of mode of manure application on mean porosity (%) and water stable aggregates (%)

CONCLUSION

The sub surface application of manure improves soil physical conditions specially water transmission and aggregation which further help in better plant growth in respect of plant height, number of tillers, thousand grain weight and ultimately crop biomass and grain yield. The water productivity was also found to be higher under sub surface application of manure.

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