Research Article

Response of Cotton to Application of Organic and Inorganic Source of Nutrients in Semi-Arid Climate

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Abstract | Use of organic manures in agriculture is considered as environmental friendly, carbon smart and an economical approach to get maximum output in existing agricultural production systems. Unselective use of organic manures is often used in the agriculture to improve soil health but it cannot significantly increase yield. Application of organic and inorganic source of nutrients can uplift the economics of existing cotton based production systems by improving soil health and reducing the cost of inorganic nutrients per unit area. This study was executed to quantify the best possible combination of integrated nutrients application for cotton crop. The effect of different combination of mineral/inorganic nitrogen (N), farm yard manure (FYM: comprised of cow dung) , poultry manure and slurry (waste product of biogas plant that uses manure of all kind of farm animals to produce biogas) were investigated to figure out the best possible combination for cotton crop. Different combinations were; T_1= control (recommended fertilizer dose 145-56-62 NPK kg ha^{-1}); T_2= poultry manure (8 t ha^{-1}); T_3= FYM (10 t ha^{-1}); T_4= slurry (10 t ha^{-1}); T_5= urea 30 kg ha^{-1}+ poultry manure 6 t ha^{-1}, T_6= urea 30 kg ha^{-1}+ FYM 8 t ha^{-1}; T_7= urea 30 kg ha^{-1}+ slurry 8 t ha^{-1}; T_8= urea 60 kg ha^{-1}+ poultry manure 3 t ha^{-1}; T_9= urea 60 kg ha^{-1}+ FYM 4 t ha^{-1}; T_{10}=urea 60 kg ha^{-1}+ slurry 4 t ha^{-1} . Treatments were laid out in field according to randomized complete block design with three replications. The results revealed the significant high response of treatment where combination of 30 kg urea ha^{-1} +8 t FYM ha^{-1} was applied. This treatment resulted in taller plants (121 cm), more number of sympodial branches (19.9), more number of bolls per plant (26), higher boll weight (3.6 g), higher seed cotton yield (1792 kg ha^{-1}) and benefit cost ratio (BCR) (1.8:1) followed by the treatment where 30 kg urea ha^{-1} was applied in combination with 8 t ha^{-1} slurry. In conclusion, combined application of urea and FYM @ 30 kg ha^{-1} and 8 t ha^{-1}, respectively could be the economical approach to attain the higher seed cotton yield.

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Introduction

In Pakistan, cotton is grown as a major cash crop. Its contribution in Pakistan's GDP and value addition is about 0.8% and 4.5% respectively (GOP, 2018-19). Productivity of cotton is affected by several factors that might be climate and edaphic such as soil fertility, irrigation, improper use of nutrients and pesticide (Bakhsh *et al.*, 2005). However, among these, soil fertility is considered as a crucial factor which has considerable impact on crop productivity (Blaise *et al.*, 2004; Gete *et al.*, 2010). Being a dynamic concept, soil fertility is affected by the climatic conditions of the area and cultural practices (Ayoub, 1999).

Soil fertility can be enhanced by mineral fertilizer application (Haq *et al*., 2014). However, imbalance use of mineral fertilizer (Getachew *et al*., 2014) and conventional cultural practices; such as burning of crop residues are reducing organic matter contents of soil ultimately disturbing optimum soil chemical and biological characteristics (Tejada and Gonzalez, 2003). This condition could be evaded by the incorporation of manures that can supply essential nutrient elements and improve soil organic contents (Dejene and Lemlem, 2012).

Soil health and plant growth can be improved by the addition of organic manures. However, these effects of applying too much inorganic fertilizer can be harmful for crops and the medium. Mineral fertilizers are not only a rich source of nutrients but these nutrients are also in available form that can be readily taken up by plants to boost their growth and development processes. Nonetheless, the excessive use of mineral fertilizer increased the nutrient loss which can cause contamination of ground water. It also reduces the soil microbial activities in the soils and plants become more prone to the attack of detrimental insects (Chen, 2006). Moreover, the role of organic manure in crop production is also important (Usman *et al*., 2013). Physical characteristics of soil can be improved by the application of organic manures. This practice increased the porosity of soil (Dejene and Lemlem, 2012). Decomposition of organic manures results in the accumulation of nutrients in soil, moreover the unavailable form of nutrients present in soil also become available because of the activity of microorganisms as these microorganisms use this organic manure as source of food. Besides these all, there are also some shortcomings of the use of organic manure i.e. slow decomposition and low nutrient contents.

Moreover, soils in most of the areas of Pakistan are poor in major soil nutrients, organic matter and have high pH also less acquisition of applied nutrients (Abbas *et al*., 2012). Hence the efficacy of applied fertilizer is reduced under such conditions, which eventually badly affect the crop production (Rashid, 2006). Therefore, improper and imbalance fertilization is considered one of the key factors for declining crop yield. Imbalance fertilization not only reduces the crop yield but also decline the quality of produce (Ghaffar *et al*., 2013). Many farmers only emphasize on the application of NPK while the use of essential micronutrients is overall ignored. Therefore, the nutrients in soil are continuously declining due to intensive cultivation and sowing of high yielding varieties that result in low nutrient use efficiency (Phullan *et al*., 2017). In addition to this, pressure on fertilizer industries is increasing because of high nutrient requirement of crops (Phullan *et al*., 2017). Thus, to fulfill this increasing demand of fertilizer, the size of fertilizer import bill is going beyond our economic capacity. Hence the mineral fertilizers are expensive. Therefore, it is dire need to invent some alternative options to meet the need of crop without any burden on economy. The other sources of plant nutrients are needed to be explored owing to more cost of mineral fertilizer, low efficacy and inadequate availability (NFDC, 2008). To tackle this fact, the use of integrated nutrient management is one of the best approaches that not only increases crop production but improves nutrient use efficiency and soil health. In this approach various sources of plant nutrients are used in combination to reduce cost of cultivation without compromising yield (Shata *et al*., 2007). Nutrient use efficiency is enhanced by integrated application of both nutrient sources (mineral fertilizer and organic manures) owing to reduce leaching of nutrients in the wake of improved soil health (Tadesse *et al*., 2013). Among various organic nutrient sources, the use of farm yard manure (FYM) is the popular one. The nutrient contents of FYM are 0.05-1.50%, 0.40-0.80 and 0.50-1.90 NPK respectively (Mukund and Prabhakarasetty, 2006). Application of FYM results in better germination and plant growth owing to enhanced capacity of soil to hold water, aeration and cation exchange capacity (Sultani *et al*., 2007). For sustainable increase crop yields and tackling soil fertility depletion, the integrated use of organic and mineral fertilizers had a paramount importance (Gete *et al*., 2010; Getachew *et al*., 2014; Getachew and Tilahum, 2017). Sustainable productivity cannot be achieved by using inorganic fertilizer or organic sources alone, it has also be shown in many research findings (Godara *et al*., 2012). Hence to improve crop growth and soil health the integrated nutrient management should be practiced (Han *et al*., 2016). Integrated nutrient management comprised of combined use of organic and inorganic mineral fertilizer and it is considered as a feasible approach to maintain soil fertility and improve crop productivity (Abedi *et al*., 2010). Hence present study was designed to find out the optimum and economic integrated dose of organic and synthetic fertilizer to obtain optimum seed cotton yield.

Materials and Methods

Experimental site, weather and soil

These research trials were conducted at experimental area of Agronomic Research Station, Khanewal (30.29°N, 71.93°E) during three consecutive years i.e. 2016, 2017 and 2018. Khanewal has a semi-arid climate. Annual maximum and minimum temperature is 42.3°C and 5.3°C, respectively whereas the average rainfall is 166 mm in a year.

Treatment

Ten treatments were designed for this experiment which were T_1= control (recommended fertilizer dose 145-56-62 NPK kg ha^{-1}); T_2= poultry manure 8 t ha^{-1}; T_3= FYM 10 t ha^{-1}; T_4= slurry 10 t ha^{-1}; T_5= urea 30 kg ha^{-1}+ poultry manure 6 t ha^{-1}, T_6= urea 30 kg ha^{-1}+ FYM 8 t ha^{-1}; T_7= urea 30 kg ha^{-1}+ slurry 8 t ha^{-1}; T_8= urea 60 kg ha^{-1}+ poultry manure 3 t ha^{-1}; T_9= urea 60 kg ha^{-1}+ FYM 4 t ha^{-1}; T_{10}=urea 60 kg ha^{-1}+ slurry 4 t ha^{-1}. Treatments were laid out in field according to randomized complete block design (RCBD) with three replications and net plot size of 3×9 m. During the course of study, same plots were used.

Crop husbandry

Soil was analyzed before sowing for its physical and chemical properties (Table 4). Soil of experimental site was sandy loam (alluvial), pH 8.6. EC 4 mS cm^{-1}, N contents 0.06%, P contents 6.9 ppm and K contents 206.7 ppm (Table 4). Manures were analyzed for their NPK contents (Table 5). FYM (comprised of cow dung) had NPK contents 0.54, 0.23 and 0.52%, respectively (Table 5). Poultry manure had NPK contents 1.84, 0.96 and 1.33% respectively while slurry (waste product of biogas plant that uses manure of all kind of farm animals to produce biogas) had NPK contents 0.68, 0.85 and o.96% respectively (Table 5). FYM, poultry manure and slurry were applied according to treatment layout at the time of soil preparation (Table 1). Mineral fertilizer was also applied according to treatment layout at the time of sowing (Table 2). In treatment T_1, all potassium (K) and phosphorous (K) fertilizer was applied at sowing time whereas nitrogen fertilizer was broadcasted in three equal splits i.e. 1st dose of nitrogen (N) fertilizer was applied at the time of sowing, 2nd dose was applied one month after sowing while third dose was applied at flowering stage (Table 2). Likewise, in treatments T_5 to T_{10}, N fertilizer was also applied in three equal splits i.e. 1st dose of nitrogen (N) fertilizer was applied at the time of sowing, 2nd dose was applied one month after sowing while third dose was applied at flowering stage (Table 2). Urea (N 46%), diammonium phosphate (DAP) (P_2O_5 46%) and sulfate of potash (SOP) (K_2O 50%) were used as a source of NPK. Seedbed was prepared by two cultivations followed by one planking operation. Then bed shaper was used to make beds (keeping bed and furrow width 75 cm). Plots were irrigated and sowing was done by manual dibbling (2-3 seeds per hole) on the edges of 75 cm spaced beds keeping plant to plant distance 12 cm. After sowing pre-emergence weedicide Pendimethalin (Stomp) was sprayed at the rate of 1000 ml per acre using manual sprayer. The gaps in emergence of cotton crop were filled six days after sowing. At the place of gap the soil was soften manually and seeds (6 hr soaked) were placed and covered with moist soil. Thinning was done 25 days after sowing. Dry hoeing was also done before 1st irrigation to control weeds. 1st irrigation was applied at 4 days after sowing, 2nd, 3rd, 4th irrigations were applied at 7 days interval while subsequent irrigations were applied at 12 days interval. Canal and tube well water were used to irrigate crop, however total fourteen irrigations were applied (Table 3).

Table 1: *Dates of field operations carried out during course of study.*

Field operation	Date of field operation		
	2016	**2017**	**2018**
Seed bed preparation	09-05-2016	11-05-2017	09-05-2018
Manure application	09-05-2016	11-05-2017	09-05-2018
Sowing	10-05-2016	12-05-2017	10-05-2018
Harvesting	20-10-2016	20-10-2017	20-10-2018

Table 2: *Dates of application of fertilizer during course of study.*

Dose of fertilizer	Date of application		
	2016	**2017**	**2018**
1st	10-05-2016	12-05-2017	10-05-2018
2nd	11-06-2016	13-06-2017	11-06-2018
3rd	02-07-2016	03-07-2017	02-07-2018

Observations

At maturity 20 plants from each treatment in each repeat were tagged to record plant height and yield related components. Plant height of these tagged plants was recorded (in centimeters) using meter rod and

Table 3: *Dates of application of irrigation during course of study.*

Irrigation	Date of application					
	2016		2017		2018	
	Date	Quantity of water applied (ft^3 ha^{-1})	Date	Quantity of water applied (ft^3 ha^{-1})	Date	Quantity of water applied (ft^3 ha^{-1})
1st	14-05-2016	2289	16-05-2017	2315	14-05-2018	2295
2nd	21-05-2016	1875	23-05-2017	1921	21-05-2018	1905
3rd	28-05-2016	1622	30-05-2017	1638	28-05-2018	1651
4th	04-06-2016	1621	06-06-2017	1626	04-06-2018	1652
5th	16-06-2016	1624	18-06-2017	1620	16-06-2018	1625
6th	28-06-2016	1624	30-06-2017	1620	28-06-2018	1625
7th	10-07-2016	1624	12-07-2017	1620	10-07-2018	1625
8th	22-07-2016	1624	24-07-2017	1620	22-07-2018	1625
9th	03-08-2016	1624	05-08-2017	1620	03-08-2018	1625
10th	15-08-2016	1624	17-08-2017	1620	15-08-2018	1625
11th	27-08-2016	1624	29-08-2017	1620	27-08-2018	1625
12th	09-09-2016	1624	11-09-2017	1620	09-09-2018	1625
13th	21-09-2016	1624	23-09-2017	1620	21-09-2018	1625
14th	03-10-2016	1624	05-10-2017	1620	03-10-2018	1625

then averaged to get mean plant height. Sympodial branches and number of bolls per plant were recorded from same tagged plants and then averaged to get mean values of sympodial branches and number of bolls per plant respectively. To record average boll weight 50 bolls from same tagged plants were picked and weighted (electronic compact scale: Model GT-500 manufactured by A and E labs, China) then this weight was divided by 50 (number of picked bolls) to get average boll weight. Cotton yield was assessed from the picking weight of whole plot (in kg) using weight balance (electronic compact scale: GT-500) then converted into kg per hectare to record seed cotton yield of each treatment using unit method.

Economic analysis

Byerlee (1988) procedure was followed to perform economic analysis. For this, gross income in rupees (Rs.) per hectare (ha) was calculated by multiplying seed cotton yield (kg ha^{-1}) obtained in each treatment with market rate (Rs./kg) of seed cotton. Permanent cost of production (Rs./ha) was calculated by adding the expenses incurred in all field operations which were uniform in each treatment such as seedbed preparation, sowing, weed control, irrigation and harvesting. Variable cost (Rs./ha) was calculated by adding the expenses incurred on each treatment separately. Then cost of production (Rs./ha) was calculated for each treatment by adding the permanent cost and variable cost of each treatment. Net income (Rs./ha) was calculated by subtracting the gross income from cost of production. At the end benefit cost ratio (BCR) of each treatment was calculated by dividing the net income by cost of production.

Table 4: *Physico-chemical properties of experimental soil.*

Characteristics	Unit	Value
Texture	Sandy loam (alluvial soil)	
pH		8.6
EC	mS cm^{-1}	4.0
Organic matter	%	0.6
Nitrogen	%	0.06
Phosphorus	Ppm	6.9
Potassium	Ppm	206.7

Table 5: *Composition of manures.*

Characteristics	Type of manure		
	Farm yard manure	Poultry manure	Slurry
N %	0.54	1.84	0.68
P %	0.23	0.96	0.85
K %	0.52	1.33	0.96
Organic carbon %	8.6	23.3	11.56
C:N ratio	18.3	12.7	11.3

Weather data

Annual maximum, minimum and average temperature and annual rainfall during growth seasons (2016, 2017 and 2018) is illustrated in Figures 1 and 2. During May 2016 to October 2016, mean temperature varied from 24°C to 38°C, from 25°C to 34°C during May 2017 to October 2017 and from 28°C to 39°C from May 2018 to October 2018.

Statistical analysis

Fisher's analysis of variance technique (Steel *et al*., 1997) was used to analyze data through statistical software STATISTIX 8.1 (Statistix, analytical software, Statistix; Tallahassee, FL, USA, 1985-2003). Least significance difference (LSD) test at 5% probability level was employed to compare means. Graphical presentation of data was elaborated using Microsoft office (2010) excel sheet.

Results and Discussion

Plant height of cotton was significantly affected by the treatments. Control and the application of 30 kg urea ha^{-1} + 8 t ha^{-1} FYM produced longer plants followed by the treatment 30 kg urea ha^{-1} along with 8 t ha^{-1} slurry (Table 6). Treatments significantly affected number of sympodial branches during 2017 while these were non-significant during 2016 and 2018 (Table 6). Likewise control and the application of 30 kg urea ha^{-1} + 8 t ha^{-1} FYM gave maximum number of sympodial branches followed by the treatment 30 kg urea ha^{-1} + 8 t ha^{-1} slurry (Table 6). Treatments did not differ significantly for number of bolls per plant during 2016 though they significantly affected number of bolls per plant during following two years (Table 6). More bolls per plant were recorded in control and by application of 30 kg urea ha^{-1} + 8 t ha^{-1} FYM in combination (Table 6). Treatments significantly affected average boll weight during 2017 however it was non-significant during rest of the years (Table 7). Control treatment as well as combined application of 30 kg urea ha^{-1} + 8 t ha^{-1} FYM resulted in heavier bolls of cotton (Table 7). Treatments significantly affected seed cotton yield (Table 7). More seed cotton yield was recorded in control treatment followed by the treatment where 30 kg urea and 8 t ha^{-1} FYM were applied in combination (Table 7). Considerable variation was observed in benefit cost ratio of various treatments. Maximum benefit cost ratio was noted where 30 kg urea was applied along with 8 t FYM followed by control treatment (recommended dose of fertilizer) (Figure 3).

Table 6: *Effect of fertilizer and manure on plant height, no. of sympodial branches and no. of bolls plant^{-1} of cotton.*

Treatments	Plant height (cm)				No. of sympodial branches				No. of bolls plant^{-1}			
	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean
Control (145-56-62 NPK kg ha^{-1})	115A	122A	139A	125	14.3	24.0A	22.0	20.1	17	34A	29A	27
Poultry Manure 8 t ha^{-1}	99EF	97G	112C	103	14.0	14.7E	17.0	15.2	15	25F	19E	20
Farm Yard Manure 10 t ha^{-1}	102DE	103EF	115C	107	13.3	17.3CD	13.0	14.5	15	28E	21DE	21
Slurry 10 t ha^{-1}	102DE	104EF	113C	106	14.0	15.7DE	17.0	15.6	16	26F	20DE	21
Urea 30 kg ha^{-1}+ Poultry Manure 6 t ha^{-1}	109CD	102EF	116C	109	14.0	18.0BC	18.0	16.7	16	29DE	22B-E	22
Urea 30 kg ha^{-1}+ Farm Yard Manure 8 t ha^{-1}	114A	118AB	130B	121	14.3	23.3A	22.0	19.9	17	35A	27AB	26
Urea 30 kg ha^{-1}+ Slurry 8 t ha^{-1}	113B	116BC	127B	119	15.6	22.0A	14.0	17.2	17	32BC	26ABC	25
Urea 60 kg ha^{-1}+ Poultry Manure 3 t ha^{-1}	113B	112CD	127B	117	14.6	19.7B	18.0	17.4	17	31BC	26ABC	25
Urea 60 kg ha^{-1}+ Farm Yard Manure 4 t ha^{-1}	111C	107DE	126B	115	14.6	19.0BC	12.0	15.2	17	30CD	24A-E	24
Urea 60 kg ha^{-1}+ Slurry 4 t ha^{-1}	112BC	107DE	117C	112	14.6	18.7BC	18.0	17.1	17	29DE	23B-E	23

Means followed by same letter are statistically non significant at $P \leq 0.05$; Each value is an average of three replications.

Table 7: *Effect of fertilizer and manure on average boll weight and seed cotton yield.*

	Average boll weight (g)				Seed cotton yield (kg ha^{-1})			
Treatments	2016	2017	2018	Mean	2016	2017	2018	Mean
Control (145-56-62 NPK kg ha^{-1})	3.5	3.6A	3.8	3.6	1140A	2467A	1845A	1817
Poultry Manure (8 t ha^{-1})	2.7	3.0F	3.2	3.0	871F	1925F	1673E	1490
Farm Yard Manure (10 t ha^{-1})	3.0	3.1EF	3.5	3.2	950DE	2262DE	1678E	1630
Slurry (10 t ha^{-1})	3.0	3.1EF	3.3	3.1	915EF	2255E	1734D	1635
Urea (30 kg ha^{-1}+ Poultry Manure 6 t ha^{-1})	3.0	3.2DEF	3.3	3.2	992CD	2300CD	1772C	1680
Urea 30 kg ha^{-1}+ Farm Yard Manure 8 t ha^{-1}	3.5	3.5AB	3.8	3.6	1097A	2458A	1822AB	1792
Urea 30 kg ha^{-1}+ Slurry 8 t ha^{-1}	3.2	3.4BCD	3.8	3.5	1021BC	2352B	1806B	1726
Urea 60 kg ha^{-1}+ Poultry Manure 3 t ha^{-1}	3.2	3.4BCD	3.7	3.4	1020BC	2230BC	1805B	1685
Urea 60 kg ha^{-1}+ Farm Yard Manure 4 t ha^{-1}	3.2	3.3CDE	3.6	3.4	1045B	2337BC	1793BC	1725
Urea 60 kg ha^{-1}+ Slurry 4 t ha^{-1}	3.2	3.3CDE	3.4	3.3	978CD	2303CD	1767C	1683

Means followed by same letter are statistically non significant at $P \leq 0.05$; Each value is an average of three replications.

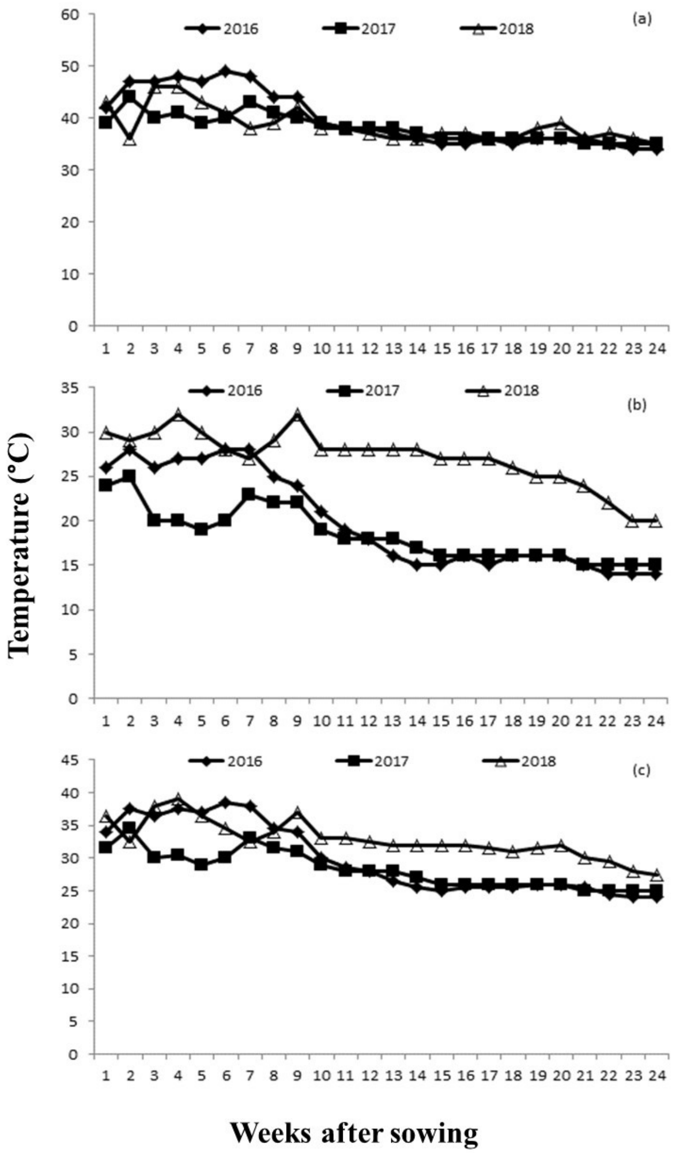

Figure 1: *Weekly temperature during crop season. (a) Maximum temperature (b) Minimum temperature (c) Average temperature.*

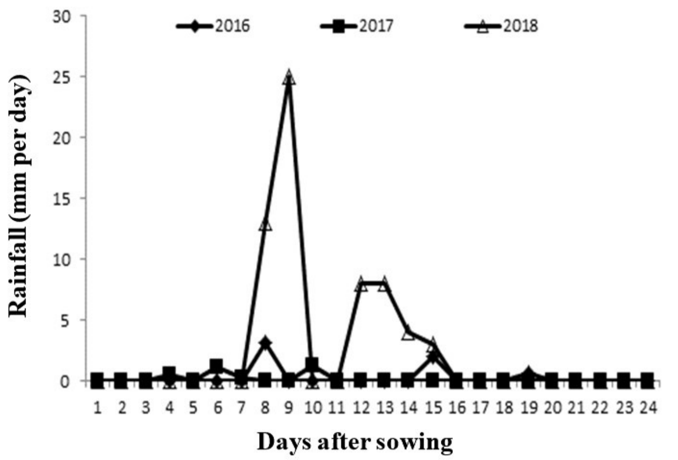

Figure 2: *Daily rainfall during crop season.*

The prime target of this field trial was to determine the combined dose of mineral fertilizer and organic manure which not only reduce the cost of production but also as efficient in sense of yield improvement as the standard recommendation of mineral fertilizer. Results of this study discovered the same i.e. application of 30 kg urea ha^{-1} + 8 t ha^{-1} FYM gave almost similar seed cotton yield as was noted in control. As mineral fertilizer has nutrients in readily available forms hence the improvement in yield related components and yield of cotton might be due to its application (Rathke *et al*., 2005). Therefore, the inclusion of mineral fertilizer has advantage over the manures owing to the rich nutrient source and it readily supplies the nutrients to the growing crops that eventually help in enhancing both, growth and yield of that crop (Meng *et al*., 2005).

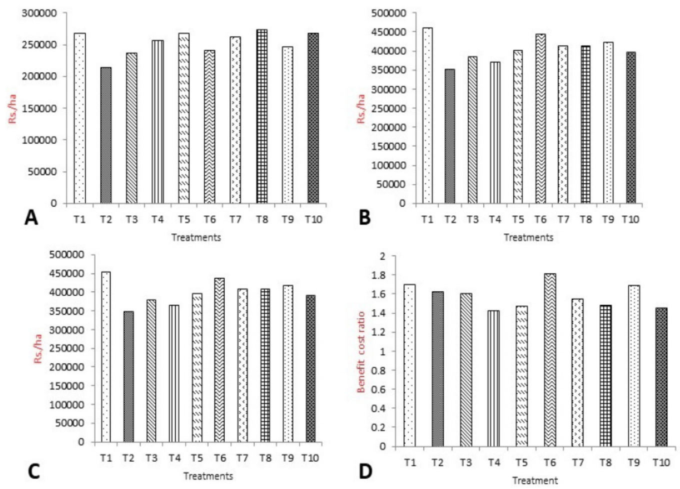

Figure 3: A: *Cost of production of various treatments;* **B:** *Gross income of various treatments;* **C:** *Net income of various treatments;* **D:** *Benefit cost ratio of various treatments.*
T_1= Control (145-56-62 NPK kg ha^{-1}); T_2= Poultry Manure (8 t ha^{-1}); T_3= Farm Yard Manure (10 t ha^{-1}); T_4= Slurry (10 t ha^{-1}); T_5= Urea (30 kg ha^{-1}+ Poultry Manure 6 t ha^{-1}); T_6=Urea 30 kg ha^{-1}+ Farm Yard Manure 8 t ha^{-1}; T_7=Urea 30 kg ha^{-1}+ Slurry 8 t ha^{-1}; T_8=Urea 60 kg ha^{-1}+ Poultry Manure 3 t ha^{-1}; T_9=Urea 60 kg ha^{-1}+ Farm Yard Manure 4 t ha^{-1};T_{10}=Urea 60 kg ha^{-1}+ Slurry 4 t ha^{-1}.

Mineral fertilizers are considered as a main source of macronutrients for crops, in most existing agricultural systems. However, excessive and continuous use of mineral fertilizers leaving harmful impacts such as waterway eutrophication, greenhouse gass emission and soil degradation that eventually influence natural biogeochemical cycles and main cause of their alteration (Amundson *et al*., 2015; Steffen *et al*., 2015). One of the example of this is diminishing of phosphate reserve in soil (Cordell and White, 2014), whereas global warming and natural resource depletion are enhancing owing to energy-intensive Haber–Bosch process for production of N-fertilize (Erisman *et al*., 2013). Therefore, it is necessary to found the alternative ways to increase crop production on sustainable basis by minimal utilization of mineral fertilizers (Foley *et al.*, 2011). The replacement of mineral fertilizer by organic manure offers one such possibility. Large amount of nutrient rich waste is produced during various municipal, industrial and agriculture processes that are dumped off. Although it can serve as organic source of nutrients by composting and processing (Paungfoo-Lonhienne *et al.*, 2012). Organically bound nutrients are held tightly in soil than nutrients obtained from mineral fertilizers therefore their chances of losses by volatilization and leeching are far less (Reganold and Wachter, 2016).

Manures (FYM, poultry manure and slurry) are rich in nutrients however the release of nutrients from manure is sluggish hence the treatments where only manures were applied gave less seed cotton yield. Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity (Godara *et al.*, 2012). However, the collective application of mineral fertilizer and manure gave optimum seed cotton yield. It might be due to the presence of mineral fertilizer which supplied the nutrients to growing crop readily (Abedi *et al.*, 2010) and fulfilled the crop nutrient requirement at early stage meanwhile the FYM completed its decomposition process and mineral nutrients present in it converted into available form after decomposition and hence fulfilled the further nutrient requirement of crop. Farmyard manure not only provide NPK but also a rich source of plant essential micronutrients. In addition to that it improves water holding capacity of soil which is of immense importance under declining water sources. Therefore, improvement in plant height, yield and yield parameters of cotton plant might be the result of availability of ideal rhizospehre conditions owing to incorporation of FYM that affect rhizospehre microbial activity and improve mobilization of soil adhered nutrients (Muneshwer *et al.*, 2001; Nevens and Reheul, 2003; Getachew *et al.*, 2016; Kassu *et al.*, 2018). Performance of plants is improved by the presence/activity of microbes including mycorrhizal fungi or nitrogen fixing symbiotic bacteria (Jacoby *et al.*, 2017). Microbial activity aided plant performance is usually put forward by three mechanisms i.e. microbial interfere the hormonal signaling in plants and manipulate it (Verbon and Liberman, 2016); microbes provide resistance against microbial pathogenic strains by outcompeting or repelling them (Mendes *et al.*, 2013) and they mineralize the nutrients which are bound with microbial molecules (van der Heijden *et al.*, 2008) hence make them available to plants. Bioavalability of various nutrients, mostly nitrogen, phosphorous and sulphar, to plants is less in natural ecosystem as they are bound with organic molecules (Singh *et al.*, 2017). Plants are dependent on the activity of microbes for acquisition of these nutrients because microbes have ability to mineralize the unavailable forms of these nutrients into readily available forms (Jacoby *et al.*, 2017). Khaliq *et al.* (2006) also recorded that the combined use of mineral fertilizer and manure not only increase yield but also the soil quality parameters.

Conclusions and Recommendations

The treatment 30 kg urea ha^{-1} + 8 t FYM ha^{-1} gave significantly higher seed cotton yield and benefit cost ratio. Hence, it is evident from this study that dose of synthetic fertilizers in cotton can be reduced by adding FYM without compromising yield and economic return. So, it is recommended to apply 8 t FYM ha^{-1} at the time of seed bed preparation of cotton and 30 kg urea subsequently should be practiced to get economically higher seed cotton yield.

Novelty Statement

Due to more application of synthetic fertilizer the cost of production of cotton goes up, this can be tackled through optimized use of mineral nutrients in combination with organic source to get economic production as well as to make soil health better.

Author's Contribution

This research was part of annual programme of research work of Agronomic Research Station, Khanewal. Saba Iqbal and Muhammad Luqman conducted the experiment and collected data. Asmat Ullah and hafiz Muhammad Nasrullah helped in its execution, data analysis, review and edition. Saba Iqbal wrote the draft of paper. All other authors made necessary improvements in it.

Conflict of interest

The authors have declared no conflict of interest.

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