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Green Manuring for Moisture Conservation and Wheat Yield Improvement in Rainfed Agriculture

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Abstract:
Green manure crops are considered to be an integral part of any cropping system in rainfed Agriculture that seems to be sustainable. A study was conducted at farmers' fields district Chakwal, Pakistan during 2014-2015 and 2015-2016 to evaluate the role of green manuring for both utilization of available soil moisture and wheat yield improvement under rainfed conditions. Six farmers' sites were selected. Fields werewell ploughed before green manuring of cowpea (*Vignaunguiculata*) to conserve precipitation in Kharif season for wheatsowing in Rabi season. Cowpea was sown in the last week of June and incorporated into the soil with rotavator during last week of August. Seed rate of cowpea was 60 kg per hectare. Incorporation of cowpea was done at about 60 days after sowing (DAS). Wheat (*Triticumaestivum*) variety Chakwal-50 was sown, using 125 kgseed per hectare with row spacing of 22.5 cm in the last week of October during 2014-15 and in the first week of November 2015-16 in fields with and without green manuring.Mineralfertilizer was applied @120-80-60 kg N-P_2O_5-K_2O per hectare. Fresh biomass of cowpea was 17.39t ha^{-1} and 16.31t ha^{-1} during 2014-15 and 2015-16, respectively. It is evident from the results that performance of wheat crop was better with cowpea green manuring. Wheat grain yield was improved 13.5 per cent, wheat straw 14 per cent, plant population 4 per cent and productive tillers 7 per cent by green manuring of leguminous crop cowpea. Incorporation of cowpea as green manuring increased soil moisture contents by 11.8 per cent and 3.6 percent in 0-15 cm and 15-30 cm soil depth, respectively. Green manuring practice need to be carefully monitored for its success in relation to environmental factors, especially in rainfed parts of the world.
Keywords: Green manuring, cowpea, soil moisture, wheat, rainfed, net return

Introduction:

Soil is a God given gift and it sustains life as well. The success of agriculture mostly depends upon soil fertility. Plants get nutrition from the soil. Plants nutrients and organic matter isdecreased by the cultivation of crops. Ultimately, soil productively is decreased which affects crop growth. Thisdeficiency is overcome by the use of different kinds of fertilizers (FYM, compost, artificial fertilizer, green manuring etc.). The useof green manuring isan effective way of maintaining soil fertility. It is need of time to maintain soil fertility and increase yield per unit area. Agriculture has turned into business and every grower has desire to get maximum benefits ina short time and limited resources. So intensive cultivation is promoted and intensive cultivation potentially degrades the basic resources of agriculture. Organic matter in the soils is depleted continuously. Nutrient availability has a great relation with organic matter presence. Manifold benefits can be obtained by green manuring.

Any plant material incorporated in the soilin green or fresh formto improve soil health and productivity is known as green manure.Itis generally fast growing nitrogen fixing legume crop (cowpea, guar, sesbania, etc) that produces a large quantity of green biomass in a short period of time. Green manures are classified into two classes, non-leguminous and leguminous green manure crops. The leguminous green manure crops are comparatively better than non- leguminous green manure crops (Aynehband*et al*., 2012). Best stage of green manure incorporation into the soil is when there are green leaves, flowers and vegetative buds are present because they decompose rapidly. If the plant becomes aged, there is problem in decomposition due to the presence of complex lignin compounds (Ghosh, 2007). Inclusion of green manuring in our agricultural system not only helps to maintain but also improve the soil characteristics. Therefore, it is helpful for maximizing the yield of our major crops which ultimately support farmers economically.

Crop productivity is improved bythe use of green manure in main crops. Green manure (GM) and Farm Yard Manure (FYM) application increased wheat yield by 51% in the treated plots compared to the control. But its residual effect after one year produced 33% more grains (Ghuman and Sur 2006).Green manuring improved soil chemical properties by decreasing the level of soil salinity and pH but soil organic carbon, available N and P increased significantly and as a result maize growth was improved (Bai *et al*.,2017).The yields of wheat follow-cowpea were significantly (P<0·05) 19–20% higher than following rice(Yadav*et al*., 2003). Cotton and cowpeaproductivityincreased with land equivalence ratios of 1:4 and 1:3 and in intercrop treatments 1:1 and 2:1, respectively (Rusinamhodzi*et al.,* 2006).Production of maize can be improved by its green manuring (Soltan*et al*., 2001). When the cowpea was incorporated in the field at pod setting stage a highly significant (r=0.88)

increase was observed in dry matter and grain yield of subsequent maize crop and highest net benefits were achieved from this crop (Hirpa, 2013). The addition of *Albizialebbec* leafy biomass in soil is an environmental friendly practice (Obebamiji*et al*., 2017).

Soil properties can be improved by the use of green manure crops and ultimatelycrop yields will be enhanced (Fageria, 2007). Green manure application effects, in green manure-wheat rotation system, on aggregate stabilityof the soil, bulk density, soil available moisture, infiltration ratewere significant (Mosavi*et al*., 2012). Soil is the major component of agricultural system (Caravaca, 2001) and organic matter plays a vital role in structure stability of the soil (Annabi*et al*., 2007). Use of organic manure like green manure is one of the best recommendationsfor improvementof soil properties (Adesoji, *et al*., 2013). Soil structural properties as; porosity, aeration, conductivity, hydraulics and infiltration are associated with the soil structural properties. Macro pores in the soil are increased bypost-harvest decaying roots (Sultani, 2007). Green manuring is helpful in moisture conservation, because water storage in soil is linkedwithsoil physical properties.When sunhemp was used as a green manure in the same field where the sunflower is cultivated after the sorghum and both are exhaustive crops, infiltration rate 39% increased, soil bulk density 18% decreased and 6.5 % pore space increased, improvement in water stable aggregates by 5.4%, water holding capacity 5.5cm per hectare and hydraulic conductivity 1.0 cm per hour (Guled*et al*., 2003).7% reduction in soil bulk density was observedwith the application of only sesbania as a leguminous green manure crop and has good impact on increasing the total porosity and available water up to 17% was noted in the plot in which sesbaniawas used as a green manure crop. A decrease in soil bulk density was observed down to 5% by the application of leguminous green manure crops such as sesbania, rice bean and cluster bean and has good impact on increasing the total porosity up to the 8% and macro-pores and large meso-pores up to the 28% (Sultani*et al*., 2007). Soil organic matter (SOM) was significantly improved by incorporation of leguminous green manure. An increase of SOMwas 3.9 -11.7 per cent in the green manure treatments than in the summer fallow treatment(Zhang *et al*, 2013).Green manure crops are mostly confused with the cover crops. Cover crops are those which grow on the soil for conservation purpose and may or may not incorporated in the soil but for the green manure crop the first rule is the incorporation of crop into the soil (Singh, 2013).

Materials and Methods:

A field study was performed at farmers' fields district Chakwal during 2014-15 & 2015-16 to evaluate the performance of cowpea green manuring for efficient utilization of available soil moisture and wheat yield Improvement underrainfed conditions. Six sites were selected in different villages of Chakwal, Punjab. Fields were ploughed up before sowing of cowpea (*Vignaunguiculata*)as green manuring, in Kharif season to conserve more precipitation for sowing of wheatin Rabi season. Soil samples were collected at start of the study for physico-chemical characteristics from all experimental sites. Cowpea was sown in the last week of June and incorporated into the soil with rotavator during last week of August. Seed rate of cowpea was 60 kg per hectare. Incorporation of cowpea was done at about 60 days after sowing (DAS). Observations were recorded on biomass production of cowpea at the time of incorporation. Wheat (*Triticumaestivum*) variety Chakwal-50 was sown, using 125 kg seed per hectare with row spacing of 22.5 cm in the last week of October during 2014-15 and in the first week of November 2015-16 in the fields with and without green manuring.Soil samples were collected from depth of 0-15cm and 15-30 cm at wheat sowing for soil moisture estimation. Wheat seed was treated prior to sowing with Topsin M @ 2 gram per kg wheat seed. Mineral fertilizer was applied @120-80-60 kg N-P_2O_5-K_2O per hectare. The agronomic practices were kept uniform in the fields without and with green manuring. The rainfall, relative humidity and monthly mean temperature were recorded during growing season of the crops. Growth and yield parameters of wheat were recorded at wheat harvest. The observations like plant population, number of fertile tillers, wheat straw and grain yield were recorded by standard procedures.

Results and Discussion:

Meteorological observations

The rainfall, relative humidity and monthly mean temperature were recorded (Fig. 1-3) during growing seasons of cowpea and wheat. The rainfall during growth period of cowpea was 262 mm and 257 mm, while it was 433 mm and 168 mm for wheat growth period during 2014-15 and 2015-16, respectively. During first and second year of study, relative humidity for growth period of cowpea was 57& 77 % while for wheat; it was 84&80 %, respectively. The study of both years results revealed that monthly minimum and maximum mean temperature for cowpea growth period ranges from 23-23^{0}C & 33-35^{0}C while, it ranges from 1-16^{o}C and 17-31^{o}C during growing season of wheat, respectively. The weather data, related to rainfall and temperature showed a wide variation during growthseasons of both crops. This variation is a particular feature of the Pothwarplateau. The rainfall pattern varies from year to year and is quite scattered.

Status of experimental sites:
The study was conducted at six locations during the year 2014-15 and 2015-16. The experimental sites have two different soil textural classes; sandy loam, and sandy clay loam. The results (Table 1) indicated that soils of the experimental fields were normal. The ranges of pH_s&EC_e were 7.6-7.77 and 0.38-0.76 dSm^{-1}, respectively. The fertility status of the experimental sites was low to medium (organic matter: 0.31-0.59 per cent, available P:3.0 - 5.5 mg kg^{-1}, Ext K:60 – 110mg kg^{-1}). Overall, there exists slight variation of pH_s,EC_e and organic matter at different sites.

Soil moisture:
Soil moisture was recorded at sowing of wheat crop. Experimental results (Fig. 4-5) indicated a variation in the soil moisture during both years of study. There were more rains during the year 2014-15 but they were quite dispersed as compared to 2015-16. The results also revealed the importance of distribution of rainfall and available soil moisture for the crops. Soil moisture during the year 2014-15 was 11.2 per cent (0-15cm) &13.0 per cent (15-30cm) without green mauring.Incorporation of cowpea, as green manuring increased the values of soil moisture to 12.8 per cent (0-15cm), 13.7 per cent (15-30cm). During the year 2015-16, it was recorded 12.6 per cent (0-15cm)&14.4 (15-30cm) in the fields where green manure was not applied. Cowpea, as green manure increased soil moisture to 13.8 per cent (0-15cm)& 14.8 per cent (15-30cm). In addition to this, mean soil moisture of both years was 11.8 %(0-15cm) and 3.6 %(15-30 cm) higher in the fields where green manuring was applied. Wang *et al*; 2016 concluded that soil moisture was controlled by rainfall pattern. Further, results also highlighted the importance of green manuring, as soil moisture availability was positively affected during the both yearsof study. So, it can be concluded that green maturing has a positive impact on soil water retention, soil water holding capacity and moisture availability to the crops. The results are beneficial for rainfed agriculture, as incorporation of green manure crops will increase the net soil moisture. Green manure application has significant effects on available soil moisture and soil water infiltration rate (Mosavi*et al*., 2012).

Biomass of green manure crop:
Data (Fig.6) indicated that the range of biomass production at different sites; cowpea green manure was 14.85 to 21.88 t ha^{-1} and 11.79 to 23.26 t ha^{-1}during the year 2014-15 and 2015-16, respectively. The average cowpea biomass of six sites was 17.39 t ha^{-1}in 1st year and 16.31 t ha^{-1} during second 2ndyear of study. Total rainfall during cowpea growing season was 262 mm and 257mm.The total biomass production during the year 2014-15 was 6.6 per cent more as compared to the year 2015-16. It revealed that more rainfall (262 mm) during first year produced more cowpea biomass and less rainfall (257 mm) produced comparativelyless cowpea biomass during second year of study. Therefore, rainfall is a key determining factor in success of any green manure crop to produce enough biomass to be incorporated as green manuring. Further, biomass production for green manuring is quite variable, particularly in dry and semi-arid regions. Therefore, any green manuring programme, need to be carefully monitored for its success in relation to environmental factors, inrainfed parts of the world.An increasing trend in aboveground biomass of annuals was observed with increase in precipitation (Yan *et al*., 2015).

Crop productivity:
The results (Fig. 7) depicted that wheat grain yield was increased by the application of green manuring. Wheat grain yield was 4479 kg ha^{-1} in 2014-15 and 4120 kg ha^{-1} with green manuring in 2015-16, while and it was 3845 kg ha^{-1}in 2014-15 and 3733 kg ha^{-1}in 2015-16without green manuring. The study of both years showed that wheat grain yield was 4300 kg ha^{-1} with green manuring and 3789 kg ha^{-1} without green manuring. It was also concluded that more rainfall (433 mm) produced more yield during first year of study and second year of study rainfall was less (170 mm) and ultimately less wheat yield was produced. Overall, results of both years study indicated 13.5 per cent increase in grain yield of wheat by cowpea green manuring. Further, during first year of study (2014-15) the rain fall was more that reflectsan increase in wheat yield (16 per cent) as compared to 10 per cent during less rainfall year (2015-16) of study. Cowpea biomass may also have contributed to increase in wheat yield. Cowpeabiomass was 17.39 tha^{-1} during the year 2014-15and 16.31 t ha^{-1}during the year 2015-16. The results also showed the effect of total biomass production of cowpea on the successes of green manure. As 17.39 t ha^{-1} biomass produces 13.5 per cent more yield of wheat as compared to 16.31 t ha^{-1}. Our findings are in line with the work of Bai *et al*., 2017 and Yadav *et al*., 2006 who reported improved crop growth and yield by green manure application.

The results regarding wheat straw yield (Fig. 8) indicated that wheat straw yield was enhanced by green manuring. Wheat straw yield was 7857 kg ha^{-1} in 2014-15 and 7170 kg ha^{-1} with green manuring in 2015-16, while and it was 6513 kg ha^{-1} in 2014-15 and 6655 kg ha^{-1} in 2015-16 without green manuring. Average of both years showed that wheat straw yield was 7514 kg ha^{-1} with green manuring and 6584 kg ha^{-1} without green manuring. Results also revealed that straw yield was positively influenced by the amount of rainfall. Net increase in straw yield of wheat by cowpea green manuring was 14 per cent. Hence, it is clear from the results that

biomass yield of cowpea has positive effects on wheat straw yield. As; soil water use efficiency can be increased by incorporation of leguminous green manures in dry land system (Zhang *et al*; 2013).

Data regarding plant population (Fig. 9) indicated that cowpea green manuring improved the plant populationat all experimental sites in both years as compared to the fields without green manuring. More number of plants m^{-2} (179) was produced during the year 2014-15 as compared to control (168). During the year 2015-16, plant populationwas 209 $m^{-2}$with green manuring and 206 m^{-2} without green manuring.The mean of both years' results showed 4.5 per cent increase in plant population with application of green manuring as compared to control. Green manuring has little effect on plant population. Plant population density of Wheat was significantly affected by green manure application method and the observed responses were variable(Podolsky, 2013). However, further studies can develop a better understanding of the plant population density of wheat crop in green manuring application in rainfedconditons.Plant population is an important parameter to achieve optimum yield and it may be influenced by multiple factors.

Data pertaining to fertile tillers (Fig. 10) revealed that green manuring stood superior in performance of attaining number of tillers as compared to fields without cowpea green manuring. Green manuring of cowpea produced more number of fertile tillers m^{-2} (293) than in the fields without green manuring(261) in 2014-15.Similarly, during the year 2015-16, number of productive tillers m^{-2} (436) was obtained with application of green manure as compared to control (422). Overall, the mean of all sites during the study of both years showed 7.6 per cent increase in fertile tillers as compared to fields without green manuring. Increase in fertile tillers of wheat crop was observed in green manured fields (Khan *et al*.,1996)

Economic analysis:

The cost benefit analysis(Fig. 11) inferred that green manure application increased net profitability by improving grain and straw yield of wheat. Overall, the study of both years elaborated that net income obtained from wheat production was Rs 71544 ha^{-1} with green manuring of cowpea and it was Rs 61261 ha^{-1} without green manuring. The net income by green manuring was 16.8 per cent higher as compared to check. The performance of cowpea green manuring was positive and it gave net benefit of Rs 10283 ha^{-1}. Our findings are in line with Mooleki*et al*., 2016 who concluded that green is practicable and viable to summer fallowing. The results also highlighted the potential of green manure application in rainfed agriculture of Pothwar.Hirpa, 2013 concluded that by incorporation of cowpea, an increased dry matter and grain yield in subsequent maize crop was observed and highest net benefits were achieved.

Conclusion

This study highlighted the green manuring effects on sustainability and economic viability of wheat crop production in pothwarregion ofPunjab. The overall results indicated that green manuring of cowpea increased grain yield13.5 per cent, straw yield 14 per cent, fertile tillers 7 per cent, plant population 4 per cent and soil moisture 11.8 per cent. Distribution of rainfall at critical crop growth stages is also very important by ensuring the adequate soil moisture availability. The results led to the conclusion that green manuring of cowpea appeared to be useful and effective for growth and development of succeeding wheat crop. Further studies focusing on the effects of different green manure crops on soil health and crop productivity are needed under varying rainfed conditions.

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Table 1:Physico- chemical characteristics of experimental sites

Location	pH_s	ECe (dSm^{-1})	OM (%)	Avail. P ($mg\ kg^{-1}$)	Ext.K ($mg\ kg^{-1}$)	Texture
Location 1	7.69	0.38	0.31	4.3	88	Sandy loam
Location 2	7.77	0.71	0.50	4.3	110	Sandy loam
Location 3	7.86	0.72	0.59	3.0	60	Sandy loam
Location 4	7.74	0.72	0.55	4.1	86	Sandy clay loam
Location 5	7.75	0.76	0.42	5.5	110	Sandy loam
Location 6	7.70	0.51	0.38	2.5	98	Sandy clay loam

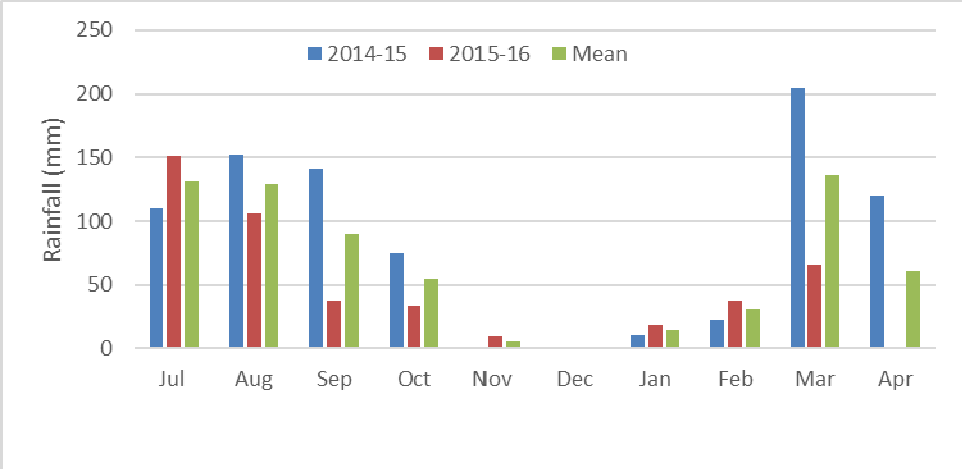

Figure1: Rainfall distribution during growing season of crops

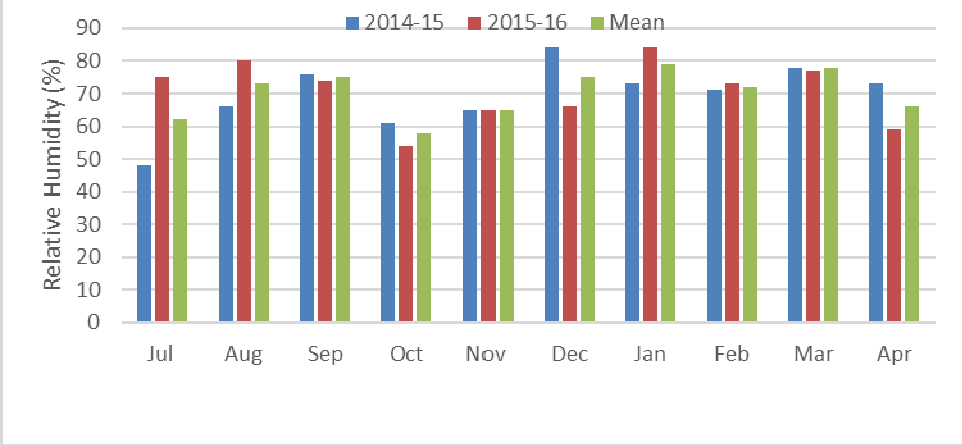

Figure2: Relative humidity during growing season of crops

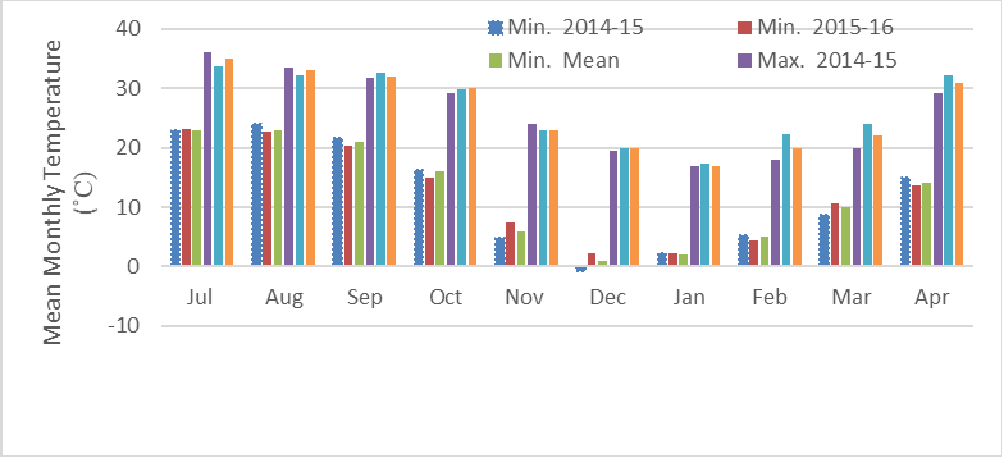

Figure 3: Mean monthly Temperature during growing season of crops

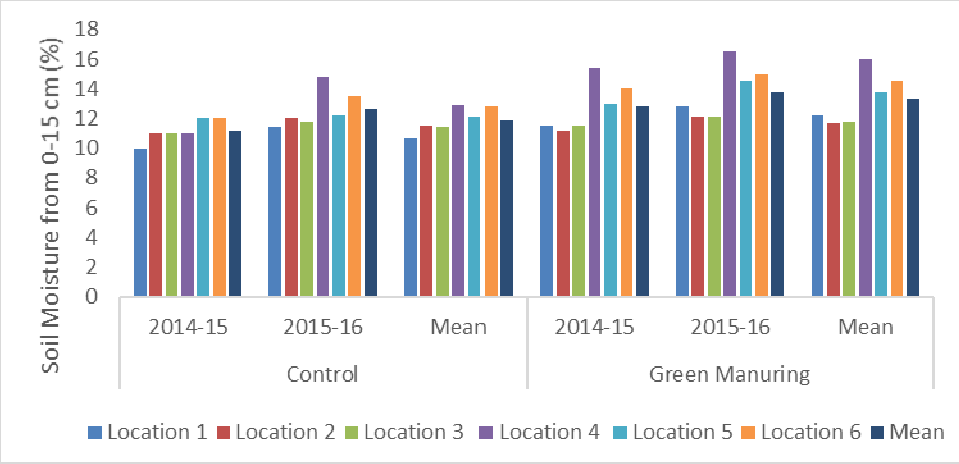

Figure 4:Effect of green manuring on soil moisture contents at wheat sowing

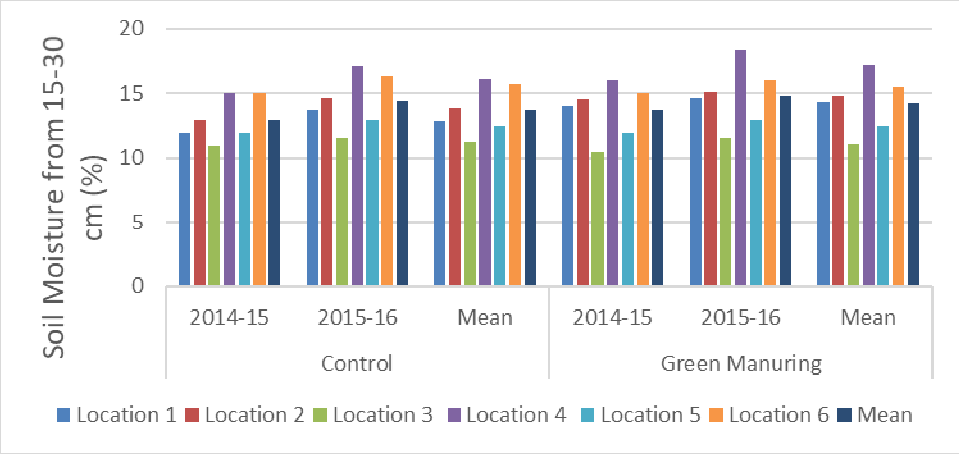

Figure 5: Effect of green manuring on soil moisture contents at wheat sowing

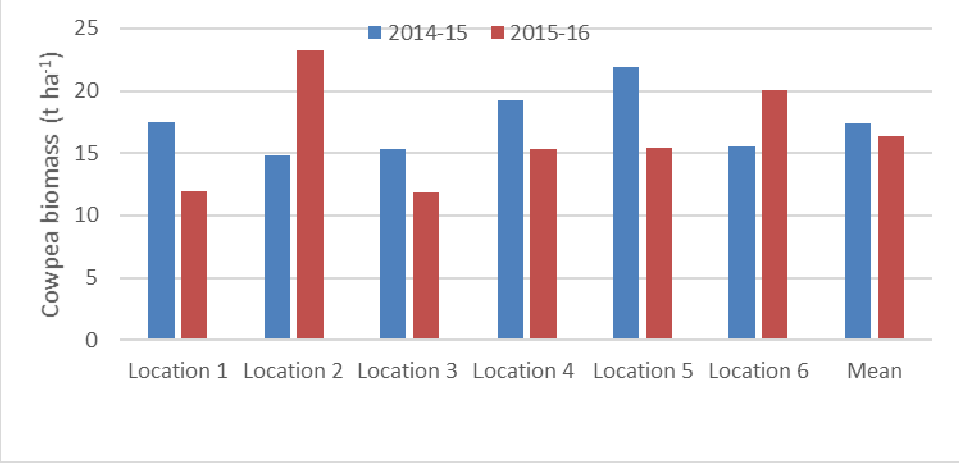

Figure 6: Cowpea performance at experimental sites

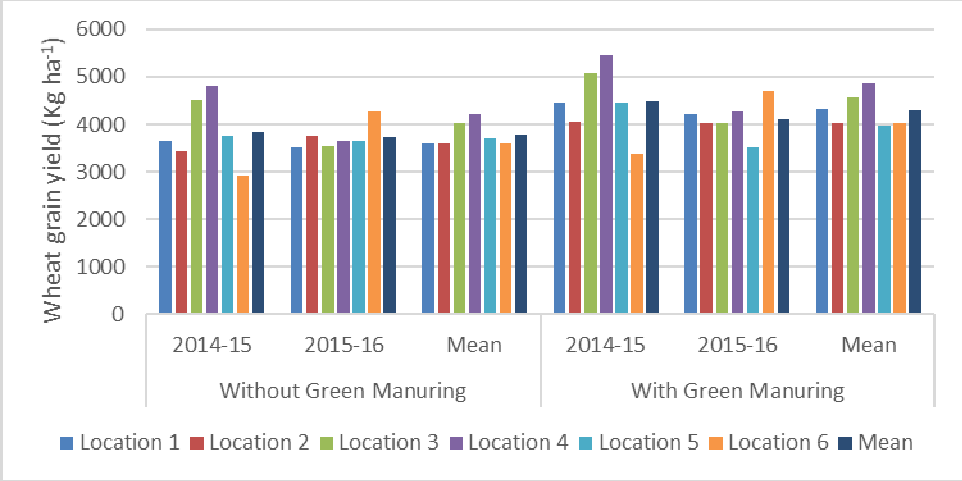

Figure 7: Effect of green manuring on wheat grain yield

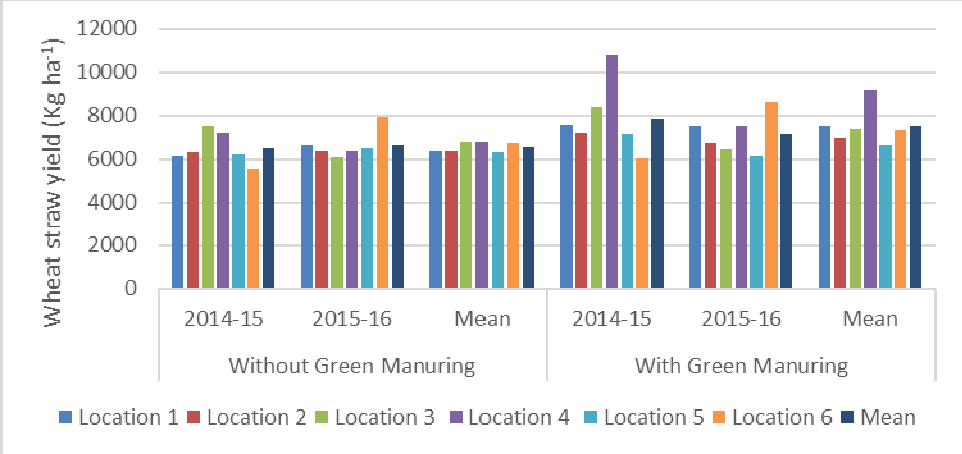

Figure 8: Effect of green manuring on wheat straw yield

Figure 9: Effect of green manuring on plant population

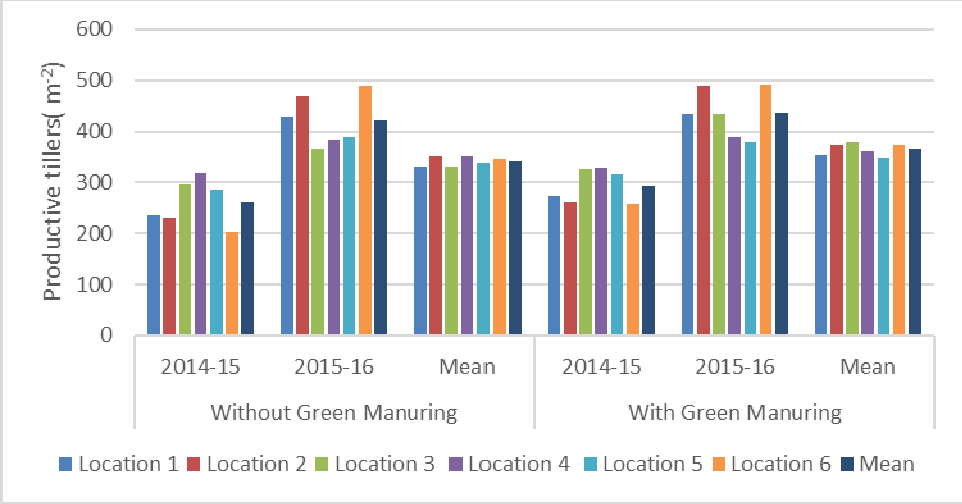

Figure 10:Effect of green manuring on productive tillers of wheat

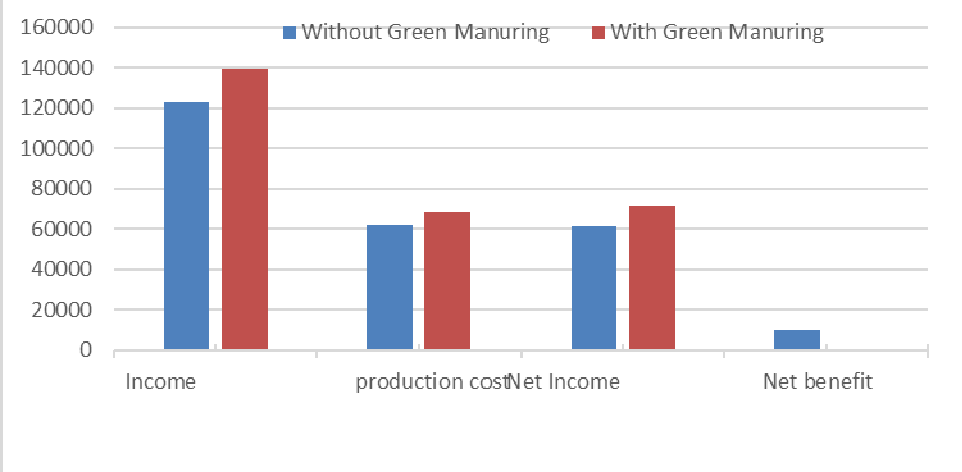

Figure 11: Cost and returns analysis of green manuring for wheat production