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Productivity of cotton wheat cropping system as influenced by *in situ* green manuring under semi arid environment

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ABSTRACT: The experiment was conducted in 2012-2013 and 2013-2014 to know the effect of *in situ* green manuring of legumes as intercrops in cotton with recommended dose of fertilizers of main crop *i.e.* cotton and residual effects of legumes in succeeding wheat crop at Agronomy Research Area, CCS Haryana Agricultural University, Hisar. Treatments comprises of cotton intercropped with cowpea (*Vigna unguiculata*.), dhaincha (*Sesbania aculeata*), cluster bean (*Cyamopsis tetragonoloba*), sunhemp (*Crotolaria juncea*) and sole cotton. Significantly higher seed cotton yield was recorded under *in situ* green manuring of sunhemp and dhaincha during both the crop seasons. Intercropping of legume crops in cotton did not have significant effect on yield of succeeding wheat crop. Cotton intercropped with dhaincha and sunhemp gives significant higher wheat equivalent yield than other intercropped legumes and sole cotton during both crop seasons. Higher HUE in cotton was observed in T_4: cotton + sunhemp, where as HYTE, HTUE and PTUE were at par in all the treatments and higher RUE was observed in the treatment T_4: cotton + sunhemp (1:2) during *kharif* and *rabi* of both years.

Key words : Cotton wheat cropping system, energy utilization, *in situ* green manuring

Cotton popularly known as "White Gold" is the most important fibre crop in the world. The seed contains good percentage of edible oil and residual cake is rich in proteins and used as cattle feed. Intercropping is an important practice to increase total yield per unit area. This system is used in many parts of the world, especially in the regions where small farmers intensively utilize the limited land area (Metwally *et al.,* 2012). Moreover, use of chemical fertilizers to the crops is a common practice, but the crop productivity is not satisfactory attained even after application of 100 per cent recommend dose of fertilizers. A traditional source of organic manure like FYM is becoming scarce as it is being used as a source of fuel (Gabhane *et al.,* 2013). Under these circumstances, appropriate agronomic practices have to be followed for the on farm generation and use of organic manures. Green manuring has been recognized as the most efficient agronomic practice for stimulating various biological transformations in the soil leading to improved soil fertility. Due to increase in the inputs cost, the net profit of the farmers from crop produce is narrowing day by day. Hence, it becomes necessary to minimize the expenses on fertilizers and at the same time sustain the crop yield and soil productivity by adopting intercropping of legumes crop. Cotton being a widely spaced crop, there is ample scope to grow green manuring crops as intercrops, without much adverse effect on main crop. Temperature plays a vital role in germination and emergence and also in subsequent growth and development, fruiting patterns and final yield. Roots generally have a lower optimum temperature range for growth than shoots, with optimum temperatures reported to be 30°C.

Cotton developmental events occur more rapidly as maximum temperature increases (Singh *et al.,* 2010) found that heat unit requirements of different genotypes of cotton increased with advancement of crop growth *i.e.* from germination to maturity. Cotton development rates are related to T_{mean} during the growing season and accumulated heat unit, which is a measure of the amount of heat energy, accumulated by a plant each day and has been used in to development of crops. A cotton plant can produce one open boll and four more bolls that are 85 per cent mature with 1000 heat unit and crop termination through defoliation at this stage of plant development results in a loss of about one percent of total expected yield but does not reduce the fiber quality.

MATERIALS AND METHODS

A field experiment was conducted during 2012-2013 and 2013-2014 at Agronomy Research Area, CCS Haryana Agricultural University, Hisar Haryana. The soil was sandy loam, pH 7.4, low in available nitrogen and organic carbon, medium in phosphorous and high in potassium content. The experiment was laid out in a randomized block design (RBD). Five treatments comprised of cotton intercropped with cowpea (*Vigna unguiculata*.), dhaincha (*Sesbania aculeata*), cluster bean (*Cyamopsis tetragonoloba*), sun hemp (*Crotolaria juncea*) and sole cotton. Cotton crop was sown by dibbling method with spacing of 67.5 x 60 cm on a well prepared seedbed after heavy pre sowing irrigation. Two seeds/hill were hand dibbled. The different intercrops *viz.,* cowpea (*Vigna unguiculata*.), dhaincha (*Sesbania aculeata*), cluster bean (*Cyamopsis tetragonoloba*), sun hemp (*Crotolaria juncea*) were also shown on the same day with hand plough. Green manuring crops were sown at 1:2 row proportions. A recommended fertilizer dose was applied on area basis (RDF-175:60:60 N, P_2O_5 and MOP kg/ha, respectively). Crop was irrigated as and when required depending on the rainfall and evaporative demand of the atmosphere. The cutting of all the green manuring crops was done at 60 days after sowing and the green matter was uniformly spread between cotton rows. Weather data for 21 to 47 SMWs were used for the analysis in respective, was collected from Agrimet observatory Department of Agricultural meteorology, CCS HAU Hisar 29^0 10' N Latitude, 75^0 46' E Longitude and Altitude 215.2 m, amsl for computation of agrometeorological indices (Growing degree day (GDD), Heliothermal unit (HTU), Photothermal unit (PTU), Hydrothermal unit (HYTU), Heat use efficiency (HUE), Hydrothermal use efficiency (HYTUE) (Singh *et al.,* 2015). The sowing was done on 22^{nd} and 28^{th} May, legumes were incorporated on 23^{rd} an 29^{th} July and picking of cotton were completed during November respectively in both the year. The wheat crop was sown on 10^{th} and 15^{th} December and was harvested on 15^{th} and 20^{th} April, respectively. Base temperature (T_b) as 10°C for cotton (*kharif*) and 5 °C for the wheat crop was used.

Growing degree days (GDD)

GDD (^{0}C day) =(T_{mean}-T_b)

Where, Tmean= Daily mean air temperature in 0C

Tb = Base temperature 0C for cotton and wheat crop

Photothermal unit (PTU)

PTU (°C day) = GDD x N, Where,

Where, GDD=Growing degree day (°C Day)

N= Possible sunshine hours (hr.)

Helio thermal unit (HTU)

HTU (°C day) = GDD x n

Where, GDD= Growing degree day (°C Day) and n=actual bright sunshine hours (n)

Hydrothermal unit (HYTU)

HYTU (°C day %) =GDD x RH_a

Where, GDD= Growing degree day (°C Day) and RH_a =Average relative humidity (%)

Photo temperature (T_p)

$T_p=(T_{max}-1)/4(T_{max}-T_{min})$

Where T_p=Photo temperature (^{0}C for day time temperature)

T_{max}= Maximum temperature (°C) and T_{min}= Minimum temperature (°C)

Nyctotemperature (T_n)

$Tn=(T_{min}+1)/4(T_{max}-T_{min})$

Where, T_{max} and T_{min} are maximum and minimum temperatures (°C)

Heat use efficiency (HUE)

HUE (kg/ha°C^{-1}day^{-1}) =Biological or Economic yield (kg/ha.)/Accumulated GDD

Radiation use efficiency (RUE)

RUE (Kgha^{-1}MJ^{-1}) = Biological or Economic yield (kg/ha.)/"IPAR

Photothermal use efficiency (PTUE)

PTUE (kg/ha ^{0}C^{-1} day^{-1}) = Biological or Economic yield of field pea (kg/ha.)/Accumulated PTU.

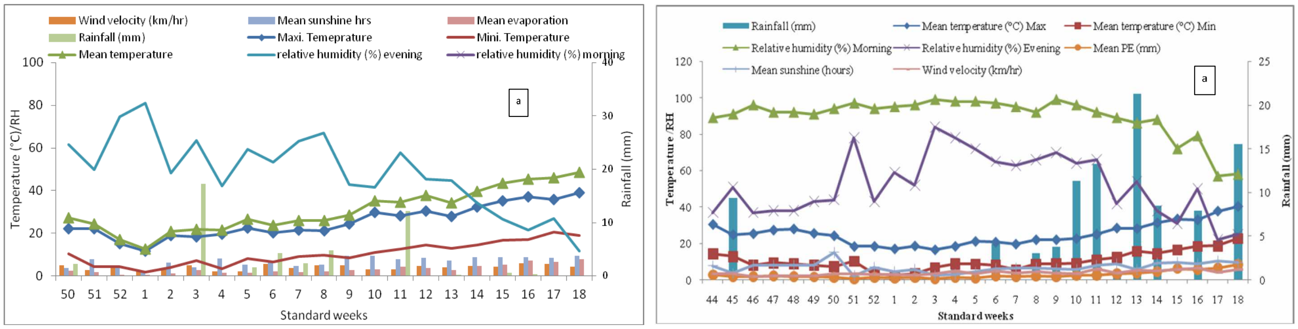
Hydrothermal use efficiency (HYTUE)

HYTUE= Biological or Economic yield of field pea (kgha^{-1})/Accumulated HYTU

RESULTS AND DISCUSSION

Prevailing weather conditions during crop period : The meteorological data for both crop seasons (*kharif* and *rabi*) have been depicted in Fig. 1a, b (10th Dec to 15th April) and (28th May to 30th November). During rabi season 2012-2013 and 2013-2014, total rainfall of 114.6 and 77.9 mm, respectively was received. Rainfall received during the months December, January, February, March and April, was 72.8 mm and 74.7 mm in 2012-2013 and 2013-2014, respectively. Average 7 rainy days were observed from sowing to harvesting (days were received >2.5 mm) in both years. Average grass minimum temperatures were 22 days observed as negative value with the range -0.3 to -6.8 °C (especially in the month of December, January and February). The weekly mean maximum (T_{mean}) and minimum temperature (T_{min}) ranged between 39.1 and 2.4°C in both the years. The weekly relative humidity (RH_{week}) ranged from 72 to 99 per cent in morning and 11.6 to 84 per cent in evening hours. The corresponding values for wind speed, sunshine hours and pan evaporation were 1.9 to 6.4 km/h, 2.0 to 15.0 hr and 0.5 to 6.2 mm/week, respectively during both the years (Fig. 1a, b). During *kharif,* 2012 and 2013, total rainfall of 420.1 and 701 mm respectively was received. Rainfall received as seasonal accumulated during June, July, August, September and October, was 417.1 mm and 693.6 mm respectively, from sowing to harvesting time period. The weekly mean maximum (T_{mean}) and minimum temperature (T_{min}) ranged between 35.9 to 16.6 °C and 29.2 to 8.0 °C during crop growing period. The weekly relative humidity (RH_{week}) ranged from 39 to 97 per cent in morning and 18.0 to 81 per cent in evening hours. The corresponding values for wind speed, sunshine h and pan evaporation were 1.4 to 10.4 km/h, 1.4 to 10.4 h and 0.7 to 12.8 mm/week, respectively in both the year (Fig. 2a, b).

Among different intercropping systems, the maximum seed-cotton yield was recorded in cotton + sunhemp, which was statistically at par with cotton + dhaincha but was significantly superior to all the other intercropping systems (Table 1). Seed cotton yield of sole cotton and cowpea as green manures did not differ significantly. Cluster bean as green manure recorded significantly higher cotton yield than



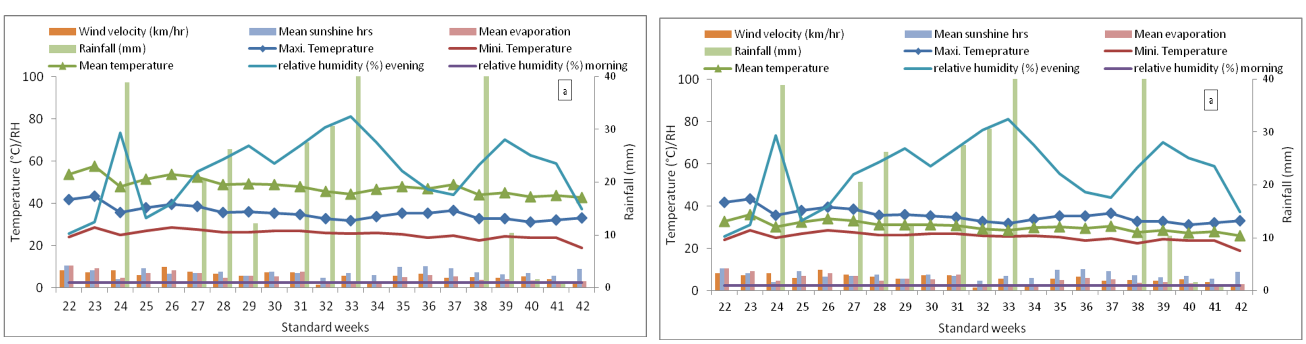
(a) (b)

Fig. 1a,b : Mean weekly values of weather parameters *rabi* 2012-2013 (a) and 2013-2014 (b)

sole cotton crop. Yield of sole cotton crop was lowest, 1962 kg/ha (2012) and 1914 kg/ha (2013). This might be due to direct addition of nutrients through organics to the available pool of soil and greater multiplication of soil microbes for the conversion of organically bound form to inorganic form particularly for nitrogen (Thimmareddy *et al.,* 2013). Similar findings were also reported by Rajpoot *et al.,* (2014). Yield of wheat crop did not differ significantly among all the treatments. However, yield of wheat crop succeeding cotton+ sunhemp was highest (3297 and 4072 kg/ha) followed by cotton+ dhaincha (3241 and 4008 kg/ha), cotton+ cowpea (3202 and 4035 kg/ha), cotton+ clusterbean (3151 and 4041 kg/ha) and sole cotton (2851 and 3772 kg/ha), respectively during *rabi* 2012-2013 and 2013-2014. Wheat equivalent yield was significantly higher in cotton + dhaincha and cotton + sunhemp (Brodrick *et al.,* 2013) depicted in Table 2.

Thermal and energy utilization by cotton and wheat crops : Agrometeorological indices computed from date of sowing to harvesting of crops during both the years respectively. During the *rabi* (2012-2013 and 2013-2014) highest accumulated heat units were observed (1393 and 1382 °C day), respectively. Cotton crop utilized the thermal heat unit 3398.35 and 3408.65 °C day during *kharif* 2013 and 2014, respectively (Table 1 and 2).

Cotton intercropped with sunhemp recorded highest and cotton alone recorded lowest thermal use efficiency ranging from 0.56 to 0.75 kg/ha°C^{-1}day^{-1} and 2.05 to 2.95 kg/ha°C^{-1}day^{-1} during *kharif* and *rabi* of both years



(a) (b)

Fig. 2a, b. Mean weekly values of weather parameters *kharif* 2012-2013 (a) and 2013-2014(b)

Table 1. Effects of *in situ* green manuring of intercropped legumes on heat, hydrothermal and energy use efficiency on seed cotton yield

Treatments	Seed cotton yield (kg/ha)		Thermal use efficiency HUE (kg/ha $^0C^{-1}day^{-1}$)		HTUE (kg/ha $^0C^{-1}day^{-1}$)		PTUE (kg/ha $^0C^{-1}day^{-1}$)		HYTE (kg/ha $^0C^{-1}day^{-1}$%)		RUE (kg/ha MJ^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cotton alone	1962	1914	0.58	0.56	0.08	0.08	0.05	0.04	0.01	0.01	2.67	2.48
Cotton + cowpea (1:2)	2011	1930	0.59	0.57	0.09	0.08	0.05	0.05	0.01	0.01	2.73	2.50
Cotton + dhaincha (1:2)	2405	2527	0.71	0.74	0.10	0.10	0.06	0.06	0.01	0.01	3.27	3.28
Cotton + cluster bean (1:2)	2031	2098	0.60	0.62	0.09	0.08	0.05	0.05	0.01	0.01	2.76	2.72
Cotton + sun hemp (1:2)	2384	2565	0.70	0.75	0.10	0.10	0.06	0.06	0.01	0.01	3.24	3.33
CD (p=0.05)	53	170	-	-	-	-	-	-	-	-	-	-

Table 2. Effects of *insitu* green manuring of intercropped legumes on heat, hydrothermal and energy efficiency utilized of wheat and wheat equivalent yield

Treatments	Wheat Yield (kg/ha)		Wheat equivalent yield(kg/ha)		Thermal use efficiency (kg/ha $^0C^{-1}day^{-1}$) HUE		HTUE		PTUE		HYTE (kg/ha $^0C^{-1}day^{-1}$%)		RUE (kg/ha MJ^{-1})	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
Cotton alone	2851	3772	8955	10776	2.05	2.73	0.28	0.38	0.18	0.24	0.03	0.04	5.42	7.16
Cotton + cowpea (1:2)	3202	4035	9458	11097	2.30	2.92	0.32	0.41	0.20	0.25	0.03	0.04	6.09	7.66
Cotton + dhaincha (1:2)	3241	4008	10723	13255	2.33	2.90	0.32	0.40	0.20	0.25	0.03	0.04	6.16	7.61
Cotton + cluster bean (1:2)	3151	4041	9470	11712	2.26	2.92	0.31	0.41	0.20	0.25	0.03	0.04	5.99	7.67
Cotton + sun hemp (1:2)	3297	4072	10714	13458	2.37	2.95	0.33	0.41	0.20	0.26	0.03	0.04	6.27	7.73
CD (p=0.05)	NS	NS	788	885	-	-	-	-	-	-	-	-	-	-

Table 3. Effects of *in situ* green manuring of intercropped legumes on accumulated agro meteorological indices during *rabi* and *kharif*

Crop	HU (^{0}C days)	HTU (^{0}C days)	PTU (^{0}C days)	Tb (^{0}C)	Tn (^{0}C)	HYTU (°C day %)	Et (mm/day)	PAR (MJ/m^2)
Wheat								
Rabi : 2012-2013	1393.00	10074.70	16121.46	2481.00	1565.00	96964.93	238.75	526.16
Rabi : 2013-2014	1382.35	9944.93	15966.55	2455.93	1578.78	100518.73	214.58	523.24
Cotton								
Kharif: 2012	3398.35	23635.14	42802.79	5872.13	4664.58	207457.25	818.28	736.15
Kharif: 2013	3408.65	25340.00	42788.41	5811.48	4745.83	229271.75	588.80	770.58

respectively. HYTE, HTUE and PTUE were *at par* in all the treatments and higher RUE was observed in the treatment T_4: Cotton + sunhemp (1:2) during *kharif* and *rabi* of both years. Higher HUE of cotton in 2013 was 0.74 kg/ha^{0}C^{-1}day^{-1} and second highest 0.71 kg/ha^{0}C-1day^{-1} in 2012 with treatment T_2. The indices HYTE, HTUE and PTUE was observed *at par* in both respective years that mean the efficient utilization of heat unit to produce the unit gram of economical or biological yield in T_4 treatment (Table 1 and 2).

The accumulated intercepted photosynthetic radiation (IPAR) was 736.1 MJ/m^2/ in 2012 and 770.6 MJ/m^2 in 2013 analyzed over the crop during the crop cycle (from date of sowing (28th May 2012, 28th May 2013) to physiological maturity in the cotton that considered the sowing to harvesting or uprooting the cotton (30th November 2012 and 30th November 2013) observed. The accumulated IPAR was 526.6 MJ/m^2/ in 2012-13 and 770.6 MJ/m^2 in 2013-14 analyzed over the wheat crop for sown (10th December 2012 and 10th December 2013) up to physiological maturity and harvested (15th April 2012-2013 and 2013-2014) in respective year. Wheat crop were found less requirement of IPAR, but higher in cotton crop due to long duration and hot loving in nature (Table 3). Nycto temperature almost same in both *rabi* season but slightly differed in case of cotton (*kharif* 2012 and 2013). Among the treatments radiation use efficiency varies 2.48 to 3.33 kg/ha MJ^{-1} and highest were found in treatment T_4 during both the years respectively (2012 and 2013).

It may be concluded that intercropping of cotton with legumes yielded significantly higher than sole cotton. However, intercropping of dhaincha and sunhemp found superior over cowpea and clusterbean in term of seed cotton yield. Thermal and energy efficiency were increased in legumes intercropped cotton.

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