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Interactive Effect of Integrated Nitrogen Management on Wheat Production in *Acacia nilotica*- and *Eucalyptus camaldulensis*-based Alley Cropping Systems

A.R. Awan[1], M.T. Siddiqui[2*], K. Mahmood[1], R. A. Khan[2] and M. Maqsood[3]
[1]*Soil Science Division, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan*
[2]*Department of Forestry, Range Management and Wildlife, University of Agriculture, Faisalabad, Pakistan*
[3]*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
[*]For correspondence: mtsiddiqui@yahoo.com

Abstract

Rapidly increasing population and shrinking farm resources are threatening the future of food security in developing countries. Under such conditions, development of agroforestry systems to meet the increasing demand of food, forage and wood is urgently needed. The objective of present research was to evaluate comparative effect of nitrogen management sources viz inorganic and organic on wheat production in *Acacia nilotica*- and *Eucalyptus camaldulensis*-based agroforestry systems established in saline environments. Three experiments were conducted at Biosaline Research Station, Pakka Anna, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan for two consecutive wheat cropping years (2011-2013). Agroforestry systems included *Acacia*- and *Eucalyptus*-wheat based systems in addition to sole wheat cropping in open field conditions. Experimental treatments comprised of nitrogen fertilizer 60, 120 kg ha^{-1} and farmyard manure 20 Mg ha^{-1} each alone and in different combinations in addition to a control -with no nitrogen and farmyard manure applied in randomized complete block design. Application of organic manure and nitrogen fertilizer separately or combined under open and agroforestry systems influenced wheat crop. The results showed that different nitrogen levels had significant ($p<0.05$) effect on number of productive tillers, grains per spike, 1000-grain weight and grain yield in each alley cropping system. Performance of yield contributing attributes was found the best in open field system whereas reduction was observed in *Acacia*- and *Eucalyptus*-wheat based systems to varying extent. Based on two years average, maximum grain yield was obtained in open field followed by *Acacia*- and *Eucalyptus*-wheat based systems with application of N 60 kg+ FYM 20 Mg ha^{-1}. These results suggest that farmers may adopt *Acacia*-based agroforestry systems for wheat production as compared to *Eucalyptus*-based systems for wheat productions in salt-affected areas. © 2015 Friends Science Publishers

Keywords: Wheat yield and yield traits; Agroforestry systems; Nitrogen response; Saline environment

Introduction

Wheat (*Triticum aestivum* L.) is the major cereal crop in many dry areas of the world and a basic food for more than one third of the world population. It is a prime source of carbohydrates and protein which has served as a staple diet for mankind (Nural-Islam and Johanson, 1987). Ecologically, wheat is adapted to a variety of climates and stressed environments including salinity. However, different biotic and abiotic stresses cause reduction in grain yield to various extents depending upon their nature and intensity. In agroforestry systems, reduction in yield of wheat is generally observed under the shade of tree crown due to resource competition (Puri and Bangarwa, 1992). Light available for intercrops depends on the quantity of light intercepted by tree canopies, and consequently, on the architecture of tree species present (Leroy *et al*., 2009). Thus, accessibility of light may be the core restrictive element for growth of understory crops in agroforestry systems.

In salt-affected soil, the problem is further intensified due to poor availability in nutrients required for proper plant growth and hence cannot upkeep nutrient requirements of upper and understory components of agroforestry system crops for higher productivity. Salt-affected soils are deficient in organic matter content reflecting the severe deficiency of nitrogen, phosphorus, potassium and micronutrients. Integrated use of organic and inorganic nitrogen sources support to sustain yield and build up soil quality for enhanced production (Nasir *et al*., 2012). Hence, application of mineral nitrogen fertilizers is an instantaneous solution to restore fertility status of these soils. However, integrated use of organic manures like farm yard manure

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with mineral nitrogen sources is advocated due to its profound benefits.

Keeping in view the importance of integrated use of organic manure and mineral nitrogen fertilizers, present study was carried out with the objective to determine relative effect of different soil amendments on biomass production of wheat with *Aacia*- and *Eucalyptus*-based agro-forestry systems established in saline environments.

Materials and Methods

Experimental Site

The research work was carried out at Bio-saline Research Station (BSRS), Pakka Anna, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan (Longitude 73°.05´E and latitude 31°.24´N) with an elevation of 190 m asl during winter seasons (2011-2013). The climate of the area is sub-tropical, semi-arid. Monthly averages of climatic parameters during the crop seasons are shown in Table 1. The soil at the station is saline sodic to sodic with medium to light textured whereas groundwater is brackish and unfit for irrigation. Detailed characteristics of soil and farm yard manure used for experimental plots are in given in Tables 2 and 3.

Table 1: Monthly average of weather data for experimental site during study period 2011-2013

	S.Rad. ($MJ/m^2.d$)	Temp.max (ºC)	Temp. min (ºC)	Rainfall (mm)	Wind (km/d)	R. H. (%)
2011-2012						
Nov. 2011	12.5	28.6	13.5	0	64.1	60.9
Dec. 2011	12.0	22.5	4.6	0	65.1	59.6
Jan. 2012	11.4	17.3	3.2	0	85.3	69.6
Feb. 2012	14.2	18.7	4.6	6	133.6	62.1
Mar. 2012	18.1	25.9	11.7	1.5	118.6	58.2
Apr. 2012	22.2	32.8	18	10.5	113.4	59.1
2012-2013						
Nov. 2012	13.3	28.4	11.1	0.0	57.3	60.9
Dec. 2012	11.5	21.4	4.5	9.0	121.4	59.6
Jan. 2013	11.3	17.5	3.4	3.1	96.8	72.7
Feb. 2013	14.6	20.8	6.0	59.5	161.1	73.6
Mar. 2013	19.6	31.2	15.0	5.0	119.7	58.1
Apr. 2013	22.3	33.5	18.7	12.9	152.1	33.6

Table 2: Analysis of soil and tube well water at the experimental field

Characteristics	Unit	Values
Soil		
pH	-	8.47-8.64
Electrical conductivity (EC)	$dS\ m^{-1}$	10.20-23.40
Sodium adsorption ratio	$Mmol_c\ L^{-1}$	44.50-67.50
Texture	-	Sandy loam
Saturation percentage	%	32.30
Bulk density	$Mg\ m^{-3}$	1.41
Total N	$g\ kg^{-1}$	0.49
Water		
pH	-	8.60
Electrical conductivity (EC)	$dS\ m^{-1}$	6.21
Residual sodium carbonate (RSC)	$Mmol_c\ L^{-1}$	21.30

Table 3: Physico-chemical characteristics of farm yard manure used in the experiments

Characteristics	Unit	Values
Total nitrogen (N)	$kg\ Mg^{-1}$	11.34
Mineral nitrogen (N)	$kg\ Mg^{-1}$	1.22
Organic carbon (C)	$kg\ Mg^{-1}$	163.00
pH	-	7.84

Experimental Design and Treatments

Alley cropping systems comprised of *Acacia nilotica* and *Eucalyptus camaldulensis* (age: 10 years and tree density: 800 trees ha^{-1}) pre-established in saline soil. Wheat (*Triticum aestivum* L. cv *Sehar-2006*) was sown in alleys 5.0 m wide in interspaces of rows of trees as understory crop. A plot size of 5 m x 5 m was used for wheat sowing with inter-row distance of wheat lines of 30 cm. The treatments included were, nitrogen applied at 60 and 120 kg ha^{-1}, farmyard manure 20 Mg ha^{-1} alone or in combination with 60 kg N ha^{-1} in addition to control with no application of nitrogen or farm yard manure (FYM). These treatments were replicated four times in a randomized complete block design.

Crop Husbandry

All agronomic and cultural practices like seed rate, irrigation, weeding and hoeing etc. were carried out unvaryingly for all the treatments in each replication of wheat crop. Farm yard manure was applied 15 days before sowing of wheat whereas mineral N with subsequent irrigations.

Light Intensity

Light intensity was recorded weekly at 1200 h by Lux meter (Lutron Lx-101 Model: LI-COR WALZ, Made in USA) in open field and each alley cropping system during the course of experimentation.

Procedure for Data Recording

Number of tillers in one meter long row were counted in four central rows in each subplot after anthesis at four different places and converted into number of tillers per unit area (m^{-2}). Data on number of grain per spike was recorded by counting grains in five spikes taken randomly in each sub-plot and then averaged. In order to determine grain yield, four central rows in each subplot were harvested, air dried, weighed and converted into t ha^{-1}. After manual threshing, 1000-grain weight was logged from produce of each subplot at random with electronic balance.

Statistical Analysis

Data was analyzed statistically by using appropriate technique (Steel *et al*., 1997) using computer software MSTAT-C and treatments were compared by applying least significance difference test at p≤0.05.

Results

Growth and Yield Parameters

Application of nitrogen inputs in inorganic and organic combinations showed improvement in yield and yield attributes of wheat in various systems as compared to control treatment (P ≤ 0.05) as discussed below:

i. Number of tillers (m^{-2}): During both years, the number of tillers was affected significantly in different alley cropping systems as compared to sole cropping (Table 4). During both the cropping years (2011-2013), the minimum number of fertile tillers was observed in open field system in control treatment and maximum with farmyard manure 20 Mg + N 60 kg ha^{-1}. Same trend was followed by agroforestry systems regarding number of fertile tillers. Comparison of light factor in all the systems - open field, *Acacia*-based and *Eucalyptus*-based systems, showed significant effect on number of tillers per unit area in all the systems. Number of tillers exhibited decreasing trend from open field with highest numbers, followed by *Acacia*- (12%) and *Eucalyptus*-based alley cropping system with 22.9% lower number of tillers.

ii. Number of grains per spike: Significant interactive effect of varying levels of nitrogen and farm manure on number of grains per spike of wheat in open field, *Acacia*-based and *Eucalyptus*-based alley cropping systems with different light intensity regimes was found (Table 5). Comparison of light factor in all the systems showed number of grains per spike decreasing trend from open field to *Acacia*-based (24%) and in *Eucalyptus*-based system (30%) lower grain numbers per spike.

iii. 1000-grain weight: Minimum 1000-grain weight was observed in open field system in control treatment and maximum 1000-grain weight with farmyard manure when applied in combination with N (20 Mg + N 60 kg ha^{-1}). Same trend was followed by alley cropping systems regarding 1000-grain weight. Comparison of light factor in all the systems under observation i.e., open field, *Acacia*- and *Eucalyptus*-based systems showed that 1000-grain weight was significantly affected in all the systems. 1000-grain weight exhibited decreasing trend from open field with highest weight followed by *Acacia*- (13%) and *Eucalyptus*-based alley cropping system with 19.3% lower grain weight (Table 6).

iv. Grain Yield (kg ha^{-1}): During both the years of study, alley cropping systems had also significant effect on wheat grain yield (Table 7). In open field system, wheat grain yield was minimum for control which increased significantly with application of nitrogen at higher level and maximum yield was obtained with application of farmyard manure (20 Mg + N 60 kg ha^{-1}). In case of alley cropping systems, same trend was observed. Comparison of light factor in all the systems showed that grain yield was significantly affected in all the systems and it exhibited decreasing trend from open field to *Acacia*-based (18.9%) and *Eucalyptus*-based alley cropping system (30.9%) respectively.

Discussion

Salinity is one of the major factors affecting crop production potential. Studies have shown that among different wheat cultivars, Sehar-2006, possesses better adaptability and higher production potential at different salinity levels (Ashraf *et al*., 2012). It also performed well on saline-sodic soil with its grain yield potential in normal soils of 4.48 t ha^{-1} in sole cropping systems (Iqbal *et al*., 2010).

In present study, wheat crop yield and yield traits were adversely affected due to shade caused by trees in both the alley cropping systems (*A. nilotica* and *E. camadulensis*-based) up to varying extent. Apart from nutrient and moisture, distribution of light transmitted under tree canopies is a limiting factor for the development of intercrops particularly at grain formation, which reduces supply of assimilates to the developing grains (Dufour *et al*., 2012). The light available for intercrops depend on quantity of light intercepted by tree canopies and consequently on the architecture of the tree species present in the alley cropping system (Leroy *et al*., 2009). Shading is known to change quality of light reaching the understory canopy; overhead canopies absorb mostly the red and blue portion of the solar spectrum so that diffuse of radiation will be rich in orange, yellow and green wavelengths to influence the amount of growth regulating hormones and thereby growth (Baraldi *et al*., 1995). In fact, shading with low PAR by associated tree species in alley cropping systems is a factor in reducing yield of understory crops. Studies have also shown that low PAR levels resulting from overhead shading significantly reduced yield of winter wheat near tree row in a Paulownia-wheat based cropping system in China (Chirko *et al*., 1999). Hence in alley cropping systems, yield and yield components are negatively affected due to the shade of trees on understory crops (Chaudhry *et al.*, 2003). This study also indicated that *A. nilotica was* the tree species where wheat grown with minimum reduction as compared to open area whereas the highest reduction was found in case of *E. camaldulensis*. The poor wheat growth showed under eucalyptus due to inhibitory effects of allelochemicals as described by Kaushik and Singh (2001); Ahmed *et al.* (2008) and Wang *et al.* (2014).

Application of organic and inorganic N-treatments had also significant effect on wheat production. Combined application of nitrogen and farm yard manure improved yield components as compared to control and half dose of nitrogen treatments. The enhancement in yield and growth

Table 4: Number of tillers of wheat as affected by different nitrogen sources in open field, *Acacia*- and *Eucalyptus*-based alley cropping systems

N management	Open field (PAR 100%)		*Acacia*-based alley cropping systems (PAR 73±3%)		*Eucalyptus*-based alley cropping systems (PAR 64±3%)	
	2011-2012	2012-2013	2011-2012	2012-2013	2011-2012	2012-2013
Control	295±7.61 d	307±6.94 e	217±5.90 c	236±8.60 d	195±8.41d	207±8.49 d
N-60 Kg ha^{-1}	337±8.96 c	345±6.52 d	297±14.80 b	334±10.70 c	260±7.25c	276±12.30 c
N-120 Kg ha^{-1}	387±9.21 b	402±9.39 b	354±13.90.a	376±13.20 ab	300±10.2b	319±10.20 ab
FYM-20 Mg ha^{-1}	365±6.58 b	381±5.49 c	319±11.80 ab	347±12.60 bc	294±8.28b	292±10.30 bc
N-60 Kg + FYM-20 Mg ha^{-1}	413±6.91 a	436±8.79 a	356±11.00 a	398±8.50 a	336±9.28a	347±11.30 a
Mean	359.00 A	374.00 A	308.00 B	338.00 B	277.00 C	288.00 C

Mean ± standard deviation. Values sharing same letters differ non-significantly (P>0.05)

Table 5: Number of grains per spike of wheat as affected by different nitrogen sources in open field, *Acacia*- and *Eucalyptus*-based alley cropping systems

N management	Open field (PAR 100%)		*Acacia*-based alley cropping systems (PAR 73±3%)		*Eucalyptus*-based alley cropping systems (PAR 64±3%)	
	2011-2012	2012-2013	2011-2012	2012-2013	2011-2012	2012-2013
Control	44.10±0.30 c	44.70±0.38 c	31.60±1.35 d	32.10±1.14 c	29.20±0.53 c	29.80±0.59 e
N-60 Kg ha^{-1}	48.30 ±0.40 bc	47.40±0.58 bc	34.40±2.05 c	34.80.91 b	31.40 ±0.80 c	31.90±0.87 d
N-120 Kg ha^{-1}	53.40±0.80 ab	52.10±0.68 b	40.30±1.79 b	40.80 ±1.09 a	34.90±1.40 b	35.30±1.07 c
FYM-20 Mg ha^{-1}	49.20 ±0.30 bc	50.60 ±0.27 b	40.20 ±1.20 b	41.20±1.52 a	39.30±1.82 a	38.70±1.21 b
N-60 Kg + FYM-20 Mg ha^{-1}	57.50±0.20 a	59.20±0.33 a	43.80±1.20 a	42.70±1.37 a	40.10±1.04 a	41.30±1.02 a
Mean	50.50 A	50.80 A	38.10 B	38.30 B	34.90 C	35.40 C

Mean ± standard deviation. Values sharing same letters differ non-significantly (P>0.05)

Table 6: 1000-grain weight of wheat as affected by different nitrogen sources in open field, *Acacia*- and *Eucalyptus*-based alley cropping systems

N management	Open field (PAR 100%)		*Acacia*-based alley cropping systems (PAR 73±3%)		*Eucalyptus*-based alley cropping systems (PAR 64±3%)	
	2011-2012	2012-2013	2011-2012	2012-2013	2011-2012	2012-2013
Control	40.40±0.46 d	40.90±0.39 c	34.70±0.57 c	35.60±0.59 d	32.20±0.88 b	33.80±0.78 c
N-60 Kg ha^{-1}	42.40±0.25 c	43.10±0.43 b	36.50±0.90 bc	37.00±0.51cd	33.50±1.48 b	34.60±0.82 bc
N-120 Kg ha^{-1}	44.10±0.35 ab	44.80±0.38 a	38.30±0.53 b	39.60±0.64 ab	35.10±0.86 ab	36.40±1.11 b
FYM-20 Mg ha^{-1}	43.4±0.22bc	44.50±0.35 a	37.20±0.37 b	38.10±0.60 bc	33.70±0.77 b	34.90±1.02 bc
N-60 Kg + FYM-20 Mg ha^{-1}	44.8±0.43a	45.70±0.20 a	40.70±0.97 a	39.90±0.86 a	37.20±1.61 a	38.40±0.67 a
Mean	43.1A	43.80 A	37.50 B	38.10 B	34.40 C	35.60 C

Mean ± standard deviation. Values sharing same letters differ non-significantly (P>0.05)

Table 7: Grain yield (t ha^{-1}) of wheat as affected by different nitrogen sources in open field, *Acacia*- and *Eucalyptus*-based alley cropping systems

N management	Open field (PAR 100%)		*Acacia*-based alley cropping systems (PAR 73±3%)		*Eucalyptus*-based alley cropping systems (PAR 64±3%)	
	2011-2012	2012-2013	2011-2012	2012-2013	2011-2012	2012-2013
Control	1.61±0.03 e	1.63±0.03 e	1.33±0.04 e	1.44±0.08 d	1.14±0.07 d	1.22±0.06 d
N-60 Kg ha^{-1}	2.46±0.04 c	2.51±0.06 d	1.90±0.07 d	2.08±0.10 c	1.65±0.08 c	1.79±0.06 c
N-120 Kg ha^{-1}	2.99±0.06 a	2.96±0.05 b	2.28±0.11 b	2.40±0.15 b	1.91±0.18 b	2.07±0.08 b
FYM-20 Mg ha^{-1}	2.68±0.06 b	2.76±0.05 c	2.13±0.09 c	2.29±0.13 bc	1.81±0.14 b	1.81±0.14 c
N-60 Kg + FYM-20 Mg ha^{-1}	3.08±0.08 a	3.15±0.06 a	2.42±0.12 a	2.68±0.17 a	2.11±0.12 a	2.32±0.07 a
Mean	2.57 A	2.61 A	2.02 B	2.18 B	1.73 C	1.84 C

Mean ± standard deviation. Values sharing same letters differ non-significantly (P>0.05)

parameters of wheat with use of nitrogen might be due to a considerable buildup of total and instantly available levels of nitrogen (Rathke *et al*., 2005). The use of mineral nitrogen has some edge over farm manure because it supplies readily the nutrients required by crop to enhance the growth and yield (Meng *et al*., 2005). Farm manure is, likewise, a rich source of nutrients which aids to improve the crop yield. The increase in yield with integrated application of nitrogen and farm manure may be due to high level of microbial activity which improved organic matter decomposition required for plant growth (Ibrahim *et al*., 2008).

Nonetheless combined application of organic and mineral nitrogen has the potential to improve yield and soil quality (Khaliq *et al*., 2006). Mineral sources of the nutrients are readily available to the plants whereas organic resources produce a slow release of the nutrients (Patra *et al*., 2000) resulting in improvement of soil properties in salt affected soils, residual effects of N for optimum crop growth from the previous year and overall enhancement of crop productivity (Singh *et al*., 2004; Anatoliy and Thelen, 2007; Shaaban *et al.*, 2013).

Negative tree-crop interactions for light and nutrients reduces crop growth rate. Additional supply of inorganic nutrients reduces tree-crop competition for nutrients resulting in increase of crop growth (Smithson and Giller, 2002). The yield attributes are mainly affected by tree species, spacing and fertility levels as affected wheat growth (Sharma *et al*., 2000; Kaushik and Singh, 2001; Smithson and Giller, 2002). Hence in present study, integrated nitrogen management delivered sufficient nutrients and organic matter to sustain crop growth, improved soil physico-chemical properties and nullified the negative tree-crop interaction for light.

Conclusion

Integrated usage of nitrogen performed better than the sole application of organic N sources and mineral N source in terms of improvement of wheat crop yield. Better response for yield of wheat was observed in open field system with full light intensity and was lower in *Acacia*-based systems and the lowest in *Eucalyptus*-based system due to difference in light intensity in these systems. Our study confirms that *Acacia*-wheat based alley cropping systems are more apposite for wheat production in saline environments.

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