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Effect on Yield and Yield Components of Wheat under Poplar based Agroforestry System

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ABSTRACT: The global community faces a dual challenge of fulfilling the nutritional requirements of rising population while still remaining environmentally and socially sustainable. Agroforestry being a low-input technology, has been found to improve food production in addition to maintain sustainability in developing countries like India. Therefore, the major challenge is to develop improved annual crop varieties that are well adapted to be grown in agroforestry systems at an ideal population density. The experiment was conducted to study growth and yield components of wheat under poplar based agroforestry and identify well adapted varieties. The research comprised of three factors, (1) two types of environments viz. open farming and under shade of poplar trees (2) eight wheat varieties and (3) three levels of plant population densities viz. high, medium and low. A split- split plot design was used to study the influence of these three factors on wheat growth parameters. A highly significant interaction among the three treatments for plant height, number of productive tillers/plant, spike length, flag leaf area (cm^2), number of grains/spike, grain weight/spike, 1000 grain weight (g) and grain yield (g), implies that the difference for these traits between levels of one treatment depends on the levels of the other two treatments. The results suggests differential response of wheat varieties to shading as well as densities. UP 2628 proves to be a promising variety for improvement for tolerance to plant population stress while UP 2785 can be a promising variety for improvement for shade tolerance.

Keywords: Agroforestry, shade tolerance, yield components, Plant population density, Population stress, Varietal response.

INTRODUCTION

Agroforestry, a sustainable land utilization system has attracted attention from scientists and pioneering farmers worldwide with its peculiar amalgam of forest trees along with annual agricultural crops (van Noordwijk *et al*., 2016). India is home to fast growing tree species that are often introduced by farmers in their agricultural landscapes in order to diversify farmer's income and maximize profitability within a short time interval. One such tree species is Poplar (*Populus deltoides* Bartr.), a winter deciduous tree that has time and again proven to be the most promising tree species grown in irrigated agro- ecosystems of the country paving the way for popularizing poplar based agroforestry as one of the potential tool for alternate land use, further preventing land fragmentation, obtaining sustainable production and amelioration of the environment. The general practice of growing trees in association with annual short lived crops will help in improving the farming infrastructure, productivity of wood based industry, fuel supply for meeting increased energy requirements, aesthetic value of agroecological landscapes and employment in the developing countries like india. (Fikreyesus *et al*., 2011) providing diverse ecosystem services (Torralba *et al.,* 2016).

The tree-based intercropping (TBI) systems generally comprise of hardwood trees such as poplar competing with annual short-lived crops for light, water, micro and macronutrients etc. Additionally, the tree components within TBI systems are capable of sequestering carbon, locking up the carbon in different tree components as well as improving the carbon status in the soil beneath (Paul *et al*., 2002; Sauer *et al*., 2007). The microclimatic conditions in agricultural landscapes can be further modified through agroforestry by enhancing the microenvironment under tree canopy favourable for crop yield and yield attributes (Chauhan *et al*., 2012). The tree-based intercropping (TBI) systems involving poplar in association with wheat (*Triticum aestivum* L.) are widely practised during *rabi* season (November-April) in northern states of Punjab, Haryana, Uttarakhand etc along with as well certain parts of central and eastern India (Sarvade *et al*., 2014).

However, agroforestry has found very little scope in the dictionary of plant breeding methods since, very few TBI systems take into consideration the attributes of field crops and if any, the main aim is the evaluation of certain varieties with respect to the yield aspect. Agroforestry usually results in a decrease in crop yield compared to the sole crop because of tree-crop competition for biological resources (Jose *et al.,* 2004). Thus, the studies based on competition effects on shoots and roots between tree and crop has opened new avenues for the breeders to rethink and come up with an elaborate and efficient breeding strategy. Since, selection is made among the crop varieties on the basis of genetic diversity to improve the stress (biotic/abiotic) resistance of crops in conventional plant breeding systems (Wolfe *et al.,* 2008), a possibility can be seen for improving the crop performance under agroforestry conditions through plant breeding techniques. Thus, population varieties can have an advantage over pure line varieties with respect to adaptation under agroforestry systems due to their recombinant genetic structure (Reiss and Drinkwater 2017). Therefore, the present investigation was undertaken to evaluate the suitability of wheat varieties under different plant densities within poplar based agroforestry system.

MATERIALS AND METHODS

Study site. The present research work was undertaken at the at the Experimental site of Agroforestry Research Centre (old site) of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, (Uttarakhand) India. The geographical location of the experimental site falls between 28°58′ N to 29°1′N Latitude and 79°24′E to 79°31′E longitudes and at an altitude of 243.84 meters above sea level. The location lies in the foothills of the Shivalik range of the Himalayas in the narrow strip called *Tarai* which has humid, sub-tropical climate comprising of cold winters and hot dry summers. The maximum daily temperature in summer may reach up to 42°C and minimum temperature in winter may fall up to 0.5°C. Generally, south-west monsoon sets in the second or third week of June and continues up to the end of September. The mean annual rainfall is about 1450 mm, of which 80-90 per cent is received during the wet season (July to September). The characteristic features of soils of tarai region are high water table, shallow depth (1.0 to 1.5 m) and calcareous nature developed from alluvial, medium to moderately coarse textures materials under predominant influence of tall vegetation and moderate to well drain conditions.

Experimental Details. The present investigation conducted during Rabi 2018-19. The poplar based agroforestry systems were established in the year 2003-04. All the poplar tree species were regularly pruned up to five year to maintain as a single stem with a spacing of 3m × 7m. The experiment was laid out in a split split plot design with three replications with 1) main plot treatment condition as wheat under-storey poplar trees and as sole wheat crop, 2) eight varieties of wheat *viz.,* UP 2572 (v1), PBW 660 (v2), C-306 (v3), UP 2628 (v4), UP 2784 (v5), UP 2785 (v6), UP 2526 (v7) and UP 2565 (v8) under sub-plot treatment and 3) plant densities at 3 levels viz. high (20,00000 plants/ha approx.), medium (10,00000 plants/ha approx.) and low (500,000 plants/ha approx.) as sub sub plot treatments. Total plot size for sowing wheat as an intercrop between poplar plantations was 2m by 5m maintaining a 1m distance between two subsequent plots. Seeds were sown in 10 cm, 20 cm and 30 cm rows apart to maintain high, medium and low plant population density, respectively. Intercultural operations were done to maintain plant population within each plot. Observations were recorded over five randomly selected plants from each plot for 10 agronomic characters viz. plant height, peduncle length, number of productive tillers/plant, spike length, number of spikelets/spike, flag leaf area (cm^2) , biological yield (g) , number of grains/spike, grain weight/spike and 1000 grain weight (g). Grain yield (g) was taken from 25 randomly selected plants within each plot. The average values for all these observations were calculated and used for the carrying out combined analyses of variance (ANOVA) with the help of Indostat 9.3 software.

RESULTS AND DISCUSSION

Analysis of variance for the traits studied under main plot, sub plot and sub sub plot. Significant effects were detected ($p \leq 0.05$) of all the three major factors viz. environment (open/shade), genotype and plant density for all evaluated characters, as well as for the interactions (Table 1 and 2). The data in revealed the mean values for all the wheat growth parameters were found to be higher under open farming than poplar based agroforestry system but significant differences among the main plot treatments were observed only for plant height, number of grains/spike, grain weight/spike and grain yield (g). Chauhan *et al*., (2012) observed a sharp decline in growth parameters of wheat crop as the age of the poplar trees advances towards maturity. Banga *et al.,* (2017) reported a similar pattern of significant differences among varieties under poplar clones for the number of spikes. Gawali *et al.,* (2015) reported that higher number of grain per spike was found in sole wheat crop than intercrop. Gill *et al.,* (2009) elucidated that wheat varieties when sown under poplar plantations during the early season i.e. mid November, performed better with respect to 1000 grain weight irrespective of the age of plantations. Sarvade *et al.,* (2014) observed improved test weight of wheat under poplar plant stand that were grown at wider spacing. Sarvade *et al.,* (2014) revealed that the reason behind significant decrease in crop yield and its attributes when sown under poplar is due to the fast growing nature of poplar plantations.

The differences among the sub plot treatments i.e. wheat crop varieties were found to be significant for all the growth parameters except number of grains/spike. This suggests the grain filling stage was equally effective for all the eight varieties. While, UP 2565 (v8) was observed to have highest mean value for plant height, peduncle length and productive tillers/plant, it was UP 2784 (v5) that performed significantly well with respect to spike length and number of spikelet/spike. Flag leaf area (cm^2) was highest for UP 2785 (v6) followed by C-306 (v3) and UP 2565 (v8). Though UP 2526 (v7) was observed to perform better with respect to biological yield (g), UP 2628 (v4) significantly outperformed the rest of the varieties in terms of grain weight/spike, 1000 grain weight and grain yield (g). The mean square of varieties was expected to show significant differences since the varieties are agronomically and morphologically distinct with respect to these traits.

Significant differences among the sub sub plot treatments i.e. response to differential plant densities were observed for number of productive tillers/plant, spike length, number of spikelets/spike, flag leaf area (cm^2), biological yield (g), grain weight/spike and grain yield/plant. This highlights a certain level of influence of plant density on overall growth of wheat crop. The genotypes with high tillering potential were observed to perform superior when maintained at reduced levels of plant density, indicating towards the capacity of wheat plant to produce a canopy that can efficiently absorb high radiations, further, maintaining a high yield potential (Whaley *et al*., 2000).

Similar results are found in the literature, with higher grain yields at reduced densities and a direct effect in the number of grains per ear (Valério *et al.,* 2013). The change in seed densities did not significantly reveal the effect of 1000 grain weight on the yield variations as observed in our study. Studies have reported that the effect of seeding density on the character 1000 grain weight is found to be negligible (Hiltbrunner *et al.*, 2005; Ozturk *et al*., 2006).

Table 1: Summary of the analysis of variance for split-split-plot design with the sources of variation main plots (open/shade), sub plots (varieties) and sub sub plots (densities), evaluated for the characters number of plant height, peduncle length, number of product tillers, spike length, number of spikelet/ spike and flag leaf area.

	DF	Plant height	Peduncle length	Number of productive tillers	Spike length	Number of spikelet per spike	Flag leaf area (cm^2)
Replicates	2	10.47 *	0.208	0.203	0.8	3.972	10.956
Main	1	41.656 **	3.453	57.381	0.004	7.111	1.45
Error A	2	0.304	0.409	4.985	0.685 ***	8.494	39.049
Sub	7	4082.599 ***	448.893 ***	22.457 ***	18.449	38.597 ***	22.689 *
Main * Sub	7	86.081 ***	29.611 ***	7.879	0.36	2.675	24.131 *
Error B	28	7.758	3.047	4.143	0.414 **	1.279	7.9
Sub sub	2	28.533	5.289	13.892 **	2.514	9.412 **	51.815 *
Main * Sub sub	2	17.758	2.7	2.506	0.164	0.792	27.804
Sub * Sub sub	14	36.445 ***	3.272	6.951 **	0.725	2.001	52.148 ***
Main * Sub * Sub sub	14	43.306 ***	5.95	5.105 *	0.912 *	1.421	57.329 ***
Error C	64	10.955	3.8	2.58	0.46	1.802	12.616
Total	143	219.38	26.768	5.334	1.426	3.779	22.026
General Mean	1	107.052	41.656	7.008	11.24	19.022	27.084
C.V. %	1	3.092	4.68	22.919	6.037	7.057	13.114

*significant at 5% probability, **significant at 1% probability

Table 2: Summary of the analysis of variance for split-split-plot design with the sources of variation main plots (open/shade), sub plots (varieties) and sub sub plots (densities), evaluated for the characters biological Yield, number of grains/spike, grain weight/spike, 1000 grain weight and grain yield.

	DF	Biological Yield	Number of grains/spike	Grain Weight/Spike	1000 grain weight (g)	Grain yield(g)
Replicates	2	1142.626	27.492	0.104	5.471	16777.08
Main	1	1857.61	2049.826 *	13.969 **	1.177	381306.3 *
Error A	2	487.467	50.271	0.091	20.064	19039.58
Sub	7	331.006 *	31.077	1.666 ***	300.635 ***	59934.82 ***
Main * Sub	7	185.181	26.714	0.272 *	15.331 *	21066.57 **
Error B	28	126.269	32.905	0.084	5.415	5583.73
Sub sub	2	2266.81 ***	52.853	1.446 ***	0.057	50633.33 ***
Main * Sub sub	2	309.629 *	47.656	0.204 *	7.252	27008.33 **
Sub * Sub sub	14	176.057 *	79.784 ***	0.618 ***	19.658 ***	18102.38 ***
Main * Sub * Sub sub	14	131.773	109.044 ***	0.643 ***	27.674 ***	11823.41 **
Error C	64	85.959	19.922	0.047	5.113	4268.056
Total	143	190.423	53.503	0.379	23.917	14151.7
General Mean	1	95.029	40.301	1.986	41.394	476.458
C.V. %	1	9.756	11.075	10.913	5.463	13.712

*significant at 5% probability, **significant at 1% probability

Effects of environment (main plot) and varieties (sub plot) on the traits studied. The influence of interaction between main plot and subplot treatments was detected for characters such as plant height, peduncle length, flag leaf area (cm^2), grain weight / spike, 1000 grain weight (g) and grain yield/plant (g). These characters may play an important role in breeding program for setting up a selection index when deciding upon the suitability of a crop variety for agroforestry system. Among the varieties, UP 2565 (v8) recorded significantly higher mean values for plant height and peduncle length whereas C-306 (v3) was observed to performed better under shade with respect to flag leaf area (cm^2). Though UP 2628 (v4) was observed as the overall best performing variety, it was UP 2785 (v6) that was found to be a more stable genotype under shade in terms of grain weight/spike, 1000 grain weight (g) and grain yield/plant (g). Therefore, wheat varieties can be said to have shown differential response to shading.

Effects of environment (main plot) and population density (sub sub plot) on the traits studied. The interaction effect between main plot and sub sub plot treatments were only observed to be significant for biological yield (g), grain weight/spike and grain yield. Biological yield was recorded highest when varieties were grown in open farming system at low population densities but least mean observed under shade at high densities. Grain weight / spike recorded highest in open farming at high plant density but least under shade when maintained at medium density. Grain yield was found to be highest when genotypes were grown in open at high population densities but significantly decreased under shade at low density level. This environment × density interaction for the grain yield showcases the importance of maintaining an ideal crop stand for wheat crop and the requisite for conducting multilocation trials for more than one year. Since, the interaction effect is found to be insignificant for number of production tillers/ plant, the optimal density level to maximize grain yield may not necessarily be related with the higher tiller production. The higher grain yields can be obtained even with lower population density for the genotypes with high tillering potential under poplar based agroforestry system (Valério *et al.*, 2013). Further, observations based on variations in plant performance as caused by differential densities are found to be particular for a given environment which confirms the direct influence of seeding density on genotypic yield (Lloveras *et al*., 2004). Therefore, a genotype can be exploited to its best performance when the plant utilizes resources directly in combination of a particular plant density so as to fit into the range of a higher yield response (Darwinkel, *et al.*, 1977).

The significant mean square for environment (main plot) and non-significant mean squares of environment by density interaction for plant height and number of grains per spike indicate that irrespective of the environment, the varieties will respond differently under different population density for these two traits.

Varietal Response to differential Plant Population Density (sub*sub sub plot). The sub plot and sub sub plot treatment interactions were observed to be significant for plant height, number of productive tillers/ plant, flag leaf area (cm^2), biological yield (g) ,number of grains/spike, grain weight/spike, 1000 grain weight (g) and grain yield (g). Highest observations were recorded by UP 2565 (v8) for plant height at high density, by UP 2565 (v8) for number of productive tillers/plant as well as flag leaf area at low density, by UP 2784 (v5) for biological yield at low density, by UP 2628 (v4) for number of grains/ spike, grain weight/spike and 1000 grain weight (g) at medium plant density but for grain yield at high plant density.

Overall performance of the varieties under varied densities under poplar based agroforestry system. The triple interaction for all the three treatments were significantly detected for variables plant height, number of productive tillers/plant, spike length, flag leaf area (cm^2), number of grains/ spike, grain weight/spike, 1000 grain weight (g) and grain yield (g). These results highlight the importance of further research to formulate a recommended level of density ideal for each specific genotype and environment.

Yield potential defined as the yield of an adapted genotype grown under optimal conditions is a critical trait for breeding under agroforestry systems. The maximum grain yield was recorded in UP 2628 at higher plant density under open farming system and thus proves to be a promising variety for improvement for tolerance to plant population stress. This is mainly resulted from the maximum expression of important yield attributes. This might be due to a more pronounced response of wheat crop to higher population densities as suggested by Nabati and Farnia (2021). Though, the lowest overall yield was obtained from UP 2572, C-306 responded more poorly with respect to grain yield under shade of poplar plantations. The varietal response to shade tolerance was also observed as highest yield among the varieties was observed for UP 2785 under poplar plantations. This variety is a promising variety for improvement for shade tolerance.

CONCLUSION

A drastic decrease in yield and its components for wheat under poplar as compared to open field (sole system) has been reported time and again by several researchers. This significant yield reduction in annual crops when intercropped with tree plantations are the result of their shading effect, competition for critical resources and below ground allelopathic reactions. Therefore, the studies on tree-crop complementary effects for resource allocation will become a major focus in years to come in order to obtain substantial yield advantages. Our study hints upon diverse responses of genotypes to the presence of trees, indicating that selection for agroforestry might be possible. Further, breeding programs should focus on optimization of plant density to enhance grain yield potential as well as improving wheat fertility in the shade.

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Conflict of Interest. The authors declare that they have no conflict of interest.

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