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Optimizing the yield potential of pigeonpea through improved agronomic practices in Vertisols

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ABSTRACT

Improved agronomic practices are required to exploit the full potential of pigeonpea crop with the integration of water, density and fertilizer which individually affect seed yield and its related traits. With the aim to understand the combined effect of these factors on the performance of hybrids and varieties this experiment was carried out at Patancheru, Telangana, India during *Kharif* 2011 and 2012 in vertisols. Three medium duration hybrids (ICPH 2671, ICPH 2740 and ICPH 3762) and varieties (BDN 711, BSMR 736 and ICPL 87119) were evaluated and the findings of the research revealed that among three treatments, T_2 [75 cm x 60 cm + 50 N kg/ha + 100 P_2O_5 kg/ha (split application at 50% as basal and 50% at 60 days after sowing) + two irrigations (during mid-flowering and mid-pod development stage)] delivered significantly higher total seed yield (3469.1 kg/ha) and biomass (7499.1 kg/ha) which is translated into higher harvest index (31.6%). However, the interactive effect of genotype × treatment interaction showed that ICPH 3762 and ICPH 2671 produced significantly greater total seed yield in T_2 (3753.5 kg/ha and 3719.3 kg/ha). Hybrid ICPH 3762 recorded the highest number of pod clusters (407.9/plant), number of pods (728.3/plant) and seed yield (179.9 g/plant) in T_3 [150 cm x 30 cm + 50 N kg/ha + 100 P_2O_5 kg/ha (split application at 50% as basal and 50% at 60 days after sowing) + two irrigations (during mid-flowering and mid-pod development stage)]. With regards to genotype × environment interaction, the highest biomass for all the genotypes was obtained in 2012 which significantly translated into higher total seed yield. Similarly, the interactive effect of environment × genotype × treatment showed that highest biomass was produced during 2012 by ICPH 2740 in T_2 at 9453.6 kg/ha. In this context, the results of the experiment revealed that the cultivation of pigeonpea hybrids and varieties following T_2 will enhance pigeonpea productivity due to superior agronomic traits.

Key words : *Agronomic practices, Hybrid, Integration, Morphological & yield traits, Pigeonpea, Varieties.*

INTRODUCTION

More than any other legume adapted to the region, pigeonpea [*Cajanus cajan* (L.) Millsp.] uniquely combines optimal nutritional profiles, high tolerance to environmental stresses, high biomass productivity and most nutrient and moisture contributions to the soil (Odeny, 2007). To overcome the problem of stagnated yield of pigeonpea from last six decades, researcher enhanced the area under cultivation significantly with more than 100 of cultivars but the productivity remains low (704 kg/ha) (Sharma *et al.*, 2013).

To increase the productivity of pigeonpea, hybrid is the good alternative (Saxena *et al.*, 2013) coupled with the adaptation of proper agronomy (Ali and Kumar, 2000 ; Sekhon *et al.*, 1996). Earlier studies reported that wider spacing (Tuppad *et al.*, 2012), higher fertilizer rate (Meena *et al.*, 2013) and irrigation (Mula *et al.*, 2013) will increase production of pigeonpea. The issues related to crop's low productivity have to be looked into the interactions of genetic materials with bio-physical resources like soil, water and plant density (Lawn and Troedson, 1990). Maximum yield in a particular cultivars and environment can be obtained from plant density where competition between the plants is low. This will be attained at an optimum plant spacing, which not only utilizes light, moisture and nutrients more efficiently but also avoids excessive competition among the plants. Bearing in mind the importance of these factors (spacing, nutrient and moisture) in intensifying crop's productivity, there is a need to conduct research aimed at understanding the crop through identifying optimum agronomic practices in different prospective production areas.

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MATERIALS AND METHODS

Pigeonpea genotypes were evaluated for various agronomic traits at Patancheru, Telangana, India during *kharif* 2011 and 2012. The investigation was conducted in split plot design (SPD) with three replications in Vertisols. The experimental material comprises of three medium maturity groups of hybrids (ICPH 2671, ICPH 2740 and ICPH 3762) and varieties (BDN 711, BSMR 736 and ICPL 87119). Genotypes were sown in three different treatments which is the combination of spacing, irrigation and fertilizer *i.e.* T_1 – control [75 cm x 30 cm + 100 kg/ha di-ammonium phosphate (DAP) as basal + No irrigation]; T_2 – 75 cm x 60 cm + [50 N kg/ha + 100 P_2O_5 kg/ha (split application at 50% as basal and 50% at 60 days after sowing)] + two irrigations (during mid-flowering and mid-pod development stage); and T_3 – 150 cm x 30 cm + [50 N kg/ha + 100 P_2O_5 kg/ha (split application at 50% as basal and 50% at 60 days after sowing)] + two irrigations (during mid-flowering and mid-pod development stage). Recommended package of agronomic practices and plant protection measures were followed as per need to raise a healthy crop.

Data like number of primary and secondary branches, number of pod clusters, number of pods, seed yield were recorded on five competitive plants, while total seed yield and biomass yield were calculated on plot basis. Harvest index (HI) was estimated by following formula:

$$HI (\%) = \frac{\text{Economical yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

The treatments were laid out in split plot design consisting three replications (as whole plot units) and six genotypes (as sub-plot units for two seasons). For each morphological trait, data were analyzed by Multi-year split plot design using SAS MIXED procedure (SAS Inst. 2002-2008, SAS V 9. 3).

RESULTS AND DISCUSSION

Effect of environments : The findings revealed that environment had significant effect on all the characters studied except grain weight and harvest index (**Table 1**). As shown in **Table 2** between two environments, 2011 produced higher numbers of primary (14.9) and secondary branches (43.8), more number of pod clusters (328.1) and pods/plant (522.0) while highest seed yield (3364.5 kg/ha) and biomass yield (7955.2 kg/ha) were recorded in 2012. However, early maturity of the genotype were observed in 2012 (165.3 days) than in 2011 (169.4 days) which support the findings of Rathore and Sharma (2011) where yield and its related traits are influenced by various environmental factors.

Effect of genotypes : Significant variations were observed on the effects of genotypes to all the characters as shown in Table 1. Among the genotypes, ICPH 2671 recorded highest number of primary (14.9) and secondary (45.0) branches, yield/plant (139.7 g) and biomass (8061.4 kg/ha) which translate to significantly higher seed yield (3285.5 kg/ha) while ICPH 3762 obtained more number of pod clusters (307.9) and pods/plant (532.8) than varieties as shown in **Table 3**. However, the highest harvest index was recorded by BSMR 736 (31.8 %). The results are in conformity with the findings of Saxena *et al.* (2013), Meena *et al.* (2013), and Tuppad *et al.* (2012) which indicated that pigeonpea hybrids have more yields and higher heterosis over the varieties.

Table 1. Statistical significance for various yield & its associated characters of pigeonpea for across the environments

Source	Df	Days to 80% maturity (no.)	Primary branches /plant (no.)	Secondary branches /plant (no.)	Pod clusters /plant (no.)	Pods per plant (no.)	Seed yield /plant (g)	Total seed yield (kg/ha)	Biomass (kg/ha)	Harvest index (%)
Environment	1	70.43**	63.13**	17.07**	19.84*	15.78*	0.01	66.61**	57.25**	0.03
Genotype	5	897.84**	15.34**	6.65**	4.33**	6.04**	2.60*	8.72**	46.24**	5.89**
Treatment	2	5.86**	8.29**	12.06**	38.43**	62.81**	42.13**	29.79**	5.59*	21.05**
Environment x Treatment	2	11.63**	0.38	1.23	0.96	3.22	0.31	4.32*	8.03**	0.09
Genotype x Treatment	10	1.28	1.31	0.57	2.06*	2.19*	2.90**	2.39**	1.18	1.9
Genotype x Environment	5	1.53	3.44**	0.17	3.96**	0.95	1.77	5.11**	7.19**	6.23
Environment x Genotype x Treatment	10	1.09	0.91	0.37	0.75	0.72	0.36	0.44	3.18**	0.83

Note : * Significant at 5% and ** significant at 1% level

Table 2. Effect of environment on yield and its related traits

Environment	Days to 80% maturity (no.)	Primary branches/ plant (no.)	Secondary branches/ plant (no.)	Pod clusters/ plant (no.)	Pods /plant (no.)	Total seed yield (kg/ha)	Biomass (kg/ha)
2011	169.4[a]	14.9[a]	43.8[a]	328.1[a]	522.0[a]	2752.9[b]	6376.9[b]
2012	165.3[b]	9.5[b]	33.6[b]	219.6[b]	414.2[b]	3364.5[a]	7955.2[a]

Note : Means followed by the same letter in a column (a-e) do not differ significantly at P = 0.05

Table 3. Effect of pigeonpea genotypes on various morphological traits for across the environments

Genotypes	Days to 80% maturity (no.)	Primary branches/ plant (no.)	Secondary branches/ plant (no.)	Pod clusters/ plant (no.)	Pods per plant (no.)	Seed yield /plant (g)	Total seed yield (kg/ha)	Biomass (kg/ha)	Harvest index (%)
ICPH 2671	168.3^{c}	14.9a	45.0^{a}	271.1^{b}	491.2^{abc}	139.7^{a}	3285.5^{a}	8061.4^{a}	28.96^{b}
ICPH 2740	173.6^{b}	12.8^{bc}	40.7^{a}	250.0^{b}	423.5^{c}	123.8^{b}	3069.1^{b}	7732.9^{b}	28.41^{b}
ICPH 3762	177.3^{a}	13.7^{ab}	43.2^{a}	307.9^{a}	532.8^{a}	135.1^{a}	3183.5^{ab}	7434.5^{c}	29.98^{ab}
BDN 711	153.3^{e}	8.4^{e}	23.6^{b}	232.0^{c}	389.4^{d}	115.7^{c}	2647.3^{c}	5880.4^{e}	31.04^{a}
BSMR 736	163.7^{d}	11.7^{d}	38.0^{a}	294.1^{ab}	500.7^{ab}	137.8^{a}	3036.5^{b}	6513.3^{d}	31.80^{a}
ICPL 87119	168.3^{c}	12.0^{c}	41.8^{a}	287.9^{ab}	471.1^{bc}	122.8^{b}	3130.4^{ab}	7374.0^{c}	29.80^{ab}

Note : Means followed by the same letter in a column (a-e) do not differ significantly at P = 0.05

Table 4. Effect of treatments on yield and its related traits for across the environments

Treatment	Days to 80% maturity (no.)	Primary branches /plant (no.)	Secondary branches /plant (no.)	Pod clusters /plant (no.)	Pods per plant (no.)	Seed yield /plant (g)	Total seed yield (kg/ha)	Biomass (kg/ha)	Harvest index (%)
T_1	167.2^{b}	11.1^{b}	30.3^{b}	201.6^{c}	333.8^{c}	93.6^{c}	2712.8^{b}	7072.7^{b}	27.7^{b}
T_2	167.1^{b}	12.4^{b}	44.1^{a}	281.1^{b}	481.4^{b}	139.4^{b}	3469.1^{a}	7499.1^{a}	31.6^{a}
T_3	167.9^{a}	13.2^{a}	41.8^{a}	338.9^{a}	589.1^{a}	154.5^{a}	2994.3^{b}	6926.4^{b}	30.2^{a}

Note : Means followed by the same letter in a column (a-c) do not differ significantly at P = 0.05

Effect of treatments : The effect of treatments significantly influenced all the characters of pigeonpea as shown in Table 1. Out of three treatments, T_2 matured the earliest (167.1 days), produced more number of secondary branches (44.1), higher seed yield (3469.1 kg/ha), biomass (7499.1 kg/ha) and harvest index (31.6%) as revealed in **Table 4**. However, T_3 produced more number of primary branches/plant (13.2), pod cluster/plant (338.9), pods/plant (589.1) and seed yield/plant (154.5 g). This data clearly indicates that the treatments in combination of wider spacing, more fertilizer and protective irrigations gave more yield and its associated traits which is in associated to the findings of Tuppad *et al.* (2012) and Meena *et al.* (2013).

Interactive effect of environment × treatment : Seed and biomass yield was significantly affected by the interaction of environment × treatment as shown in Table 1. Likewise, **Table 5** revealed that the highest seed yield was exhibited by T_2 in 2012 (3606.8 kg/ha) while T_1 in 2011 produced the lowest yield (2323.3 kg/ha). With regards to biomass, T_1 showed highest in 2012 (8132.4 kg/ha) while T_3 was the lowest in 2011 (6003.8 kg/ha) which corresponds to the findings of Mula *et al.* (2013).

Table 5. Interactive effect of environment × treatment on yield and biomass of pigeonpea

Environment	Total seed yield (kg/ha)			Biomass (kg/ha)		
	T_1	T_2	T_3	T_1	T_2	T_3
2011	2323.3^{b}	3331.4^{a}	2604^{b}	6013^{b}	7114.1^{a}	6003.8^{b}
2012	3102.2^{b}	3606.8^{a}	3384.6^{b}	8132.4^{a}	7884.1^{b}	7849.1^{b}

Means followed by the same letter in a column (a-c) do not differ significantly at P = 0.05

Interactive effect of genotype × treatment: The findings revealed that there was a remarkable interactive effect of genotype × treatment on the number of pod clusters, number of pods, yield/plant and seed yield (kg/ha) across the environments (Table 1). Meanwhile, all the genotypes tested in T_3 produced more pod clusters as compared to other treatments. However, the highest number of pod/clusters was recorded by ICPH 3762 (407.9) whereas BDN 711 was the least in T_1 at 145.2 pod clusters/plant.

Table 6 revealed that significantly more number of pods/plant where observed in ICPH 3762, ICPL 87119 and BSMR 736 with 728.3, 613.1 and 611.3, respectively in T_3 while BDN 711, ICPH 2740 and ICPL 87119 recorded the least number of pods/plant (238.3, 291.1 and 297.7, respectively) in T_1. The effect of genotypes showed greater number of pods/plant in T_3 which conforms the findings of Meena *et al.* (2013) and Tuppad *et al.* (2012).

Genotypes ICPH 3762, ICPH 2740, ICPH 2671, and ICPL 87119 produced significantly highest yield/plant with 178.9 g, 159.5 g, 155.4 g, and 149.8 g, respectively in T_3 while BDN 711 (69.3 g), ICPH 2740 (83.7 g) and ICPL 87119 (82.8 g) have lower yield/plant in T_1 (Table 6). In general, T_3 recorded higher seed yield/pant with all genotypes which is in line to the findings of Meena *et al.* (2013).

The total seed yield of ICPH 3762, ICPH 2671 and ICPL 87119 produced significantly higher yield in T_2 at 3753.5 kg/ha, 3719.3 kg/ha and 3580.4 kg/ha, respectively as shown in Table 6 and **Fig. 1** which are in conformity with results of Tuppad *et al.* (2012) and Goud *et al.* (2012).

Table 6. Interactive effect of genotype × treatment on yield and its associated traits across the environment

Geno-types	Pod clusters/plant (no.)			Pods/plant (no.)			Seed yield/plant (g)			Total seed yield (kg/ha)		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
ICPH 2671	196.9^{b}	301.5^{a}	315.1^{a}	371.9^{b}	548.8^{a}	552.8^{a}	109.1^{b}	154.6^{a}	155.4^{a}	2918.3^{c}	3719.3^{a}	3218.9^{b}
ICPH 2740	186.2^{c}	258.7^{b}	304.9^{a}	291.1^{c}	442.6^{b}	536.8^{a}	83.7^{c}	128.2^{b}	159.5^{a}	2619.6^{b}	3206.6^{a}	3381.2^{a}
ICPH 3762	275.1^{b}	240.8^{b}	407.9^{a}	438.4^{b}	431.7^{b}	728.3^{a}	116.3^{b}	110.1^{b}	178.9^{a}	2704.2^{c}	3753.5^{a}	3092.9^{b}
BDN711	145.2^{b}	262^{a}	288.7^{a}	238.3^{b}	437.6^{a}	492.4^{a}	69.3c	147.3^{a}	130.5^{b}	2448.4^{b}	3164^{a}	2329.3^{b}
BSMR 736	215.4^{b}	301.3^{a}	365.7^{a}	365.4^{c}	525.2^{b}	611.3^{a}	100.2^{b}	160.3^{a}	152.9^{a}	2716.5^{c}	3390.7^{a}	3002.2^{b}
ICPL 87119	190.9^{b}	322.2^{a}	350.7^{a}	297.7^{c}	502.4^{b}	613.1^{a}	82.8^{c}	135.9^{b}	149.8^{a}	2869.5^{b}	3580.4^{a}	2941.4^{b}

Note : Means followed by the same letter in a column (a-c) do not differ significantly at P = 0.05

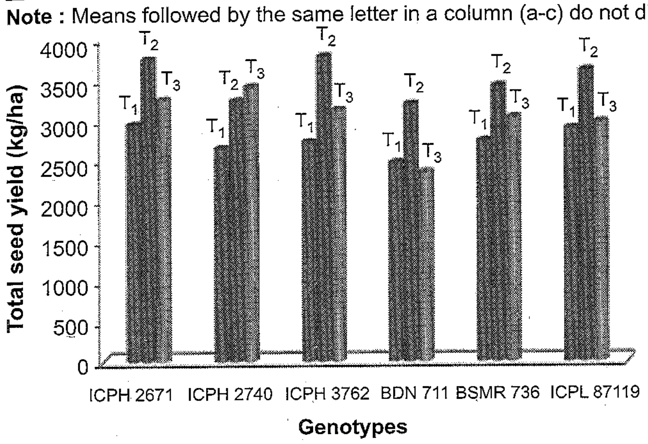

Fig. 1. Interactive effect of genotype x treatment for total seed yield (kg/ha) across the environments

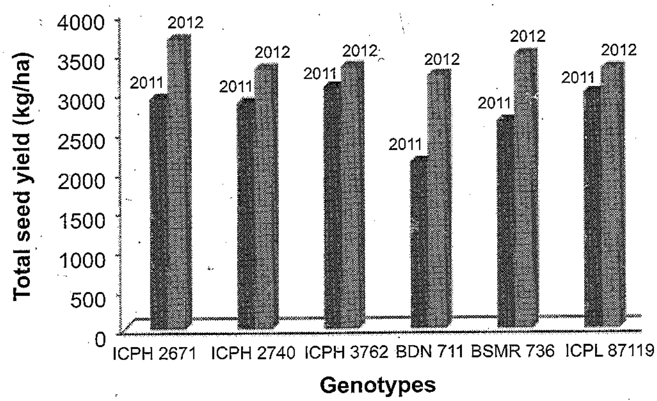

Fig. 2. Interactive effect of genotype x environment for total seed yield (kg/ha) in individual environment

Interactive effect of genotype × environment : Number of primary branches/plant, pod clusters/plant, total seed yield and biomass yield were remarkably affected by the interactive effect of genotype × environment as shown in Table 1. Genotypes ICPH 2671, ICPH 2740, ICPH 3762 and BSMR 736 produced significantly higher number of primary branches at 18.9, 15.5, 15.2 and 15, respectively in 2012 than in 2011 (**Table 7**).

The number of pod clusters obtained in ICPL 87119, BSMR 736, ICPH 3762, ICPH 2671 and ICPH 2740 was significantly greater at 379.9, 378.7, 338.3, 306.8 and 300.7, respectively in 2011 however least number of pod clusters were obtained in 2012 by ICPL 87119, ICPH 2740, BDN 711, and BSMR 736 (195.9, 199.2, 199.5, and 209.6, respectively).

Table 7 and **Fig. 2** revealed that ICPH 2671, BSMR 736, ICPH 3762 and ICPH 2740, ICPL 87119 and BDN 711 produced significantly higher seed yield in 2012 (3659.7 kg/ha, 3458.6 kg/ha, 3310.8 kg/ha, 3282.8 kg/ha, 3279.6 kg/ha and 3195.5 kg/ha, respectively) as compared in 2011.

Significantly highest biomass yield was recorded by ICH 2671, ICPH 2740, and ICPL 87119 (8774.3 kg/ha, 8708 kg/ha, and 8478.4 kg/ha, respectively) in 2012 while lowest biomass was obtained in BDN 711 (4865.7 kg/ha), BSMR 736 (5811.1 kg/ha) & ICPL 87119 (6269.6 kg/ha) in 2011 (Table 7).

Interactive effect of environment × genotype × treatment : Biomass of pigeonpea genotypes was significantly influenced by the effect of environment × genotype × treatment interaction as shown in Table 1 and **Fig. 3**. Significantly highest biomass yield were obtained in 2012 by ICPH 2740 in T_2 (9453.6 kg/ha), ICPH 2671 in T_3 (9058.9 kg/ha) and ICPL 87119 in T_1 (8862.2 kg/ha) whereas, the least

Table 7. Interactive effect of genotype × environment on yield and its related traits of pigeonpea

Geno-types	Primary branches/ plant (no.)		Pod clusters/plant (no.)		Total seed yield (kg/ha)		Biomass (kg/ha)	
	2011	2012	2011	2012	2011	2012	2011	2012
ICPH 2671	18.9^{a}	10.8^{b}	306.8^{a}	235.5^{a}	2911.3^{b}	3659.7^{a}	7348.5^{b}	8774.3^{a}
ICPH 2740	15.5^{a}	10.0^{b}	300.7^{a}	199.2^{b}	2855.4^{b}	3282.8^{a}	6757.7^{b}	8708^{a}
ICPH 3762	15.2^{a}	12.3^{a}	338.3^{a}	277.6^{a}	3056.2^{b}	3310.8^{a}	7209^{b}	7659.9^{a}
BDN711	11.5^{a}	5.2^{b}	264.4^{a}	199.5^{a}	2099.1^{b}	3195.5^{a}	4865.7^{a}	6895^{a}
BSMR 736	15.0^{a}	8.4^{b}	378.7^{a}	209.6^{b}	2614.3^{b}	3458.6^{a}	5811.1^{b}	7215.4^{a}
ICPL 87119	13.5^{a}	10.5^{a}	379.9^{a}	195.9^{b}	2981.2^{b}	3279.6^{a}	6269.6^{a}	8478.4^{a}

Note : Means followed by the same letter in a column (a-b) do not differ significantly at P = 0.05

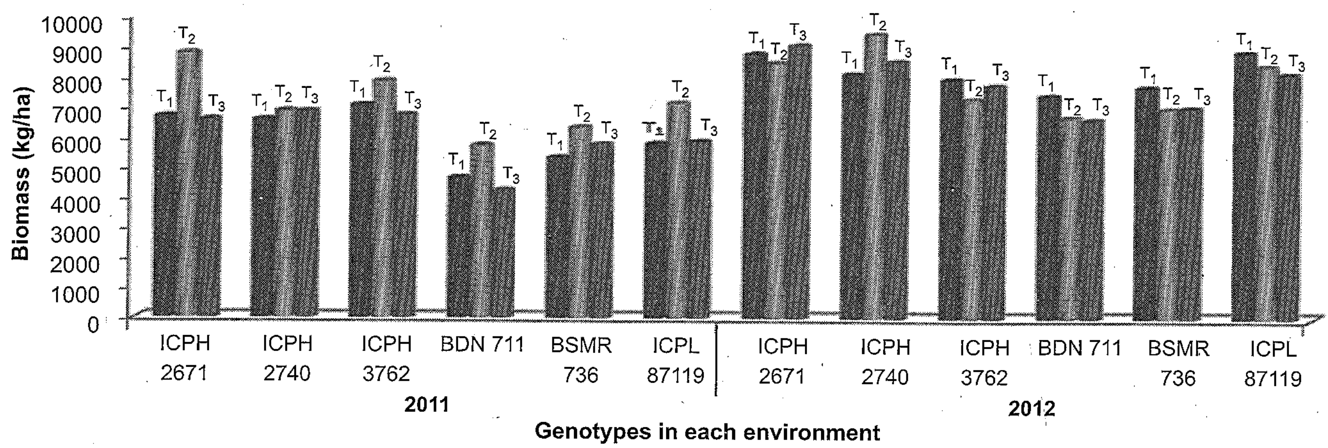

Fig. 3. Interactive effect of environment x genotype x treatment on biomass (kg/ha)

Table 8. Interactive effect of environment × genotype × treatment on biomass of pigeonpea

Environments	Genotypes	Biomass (kg/ha)		
		T_1	T_2	T_3
2011	ICPH 2671	6681.7^{bc}	8777.3^{a}	6586.5^{c}
	ICPH 2740	6573.9^{a}	6857.1^{a}	6842.1^{a}
	ICPH 3762	7051.4^{b}	7848.7^{a}	6726.8^{b}
	BDN711	4644.1^{b}	5722.4^{a}	4230.6^{b}
	BSMR 736	5325.8^{b}	6334.4^{a}	5773.2^{a}
	ICPL 87119	5800.8^{b}	7144.7^{a}	5863.4^{b}
2012	ICPH 2671	8776.9^{ab}	8487.0^{b}	9058.9^{a}
	ICPH 2740	8119.1b	9453.6^{a}	8551.4^{b}
	ICPH 3762	7952.4^{a}	7292.5^{b}	7735.0^{a}
	BDN711	7401.0^{a}	6686.4^{b}	6597.8^{b}
	BSMR 736	7683.0^{a}	6960.9^{a}	7002.5^{a}
	ICPL 87119	8862.2^{a}	8424.0^{a}	8149.1^{a}

Note.: Means followed by the same letter in a row (a-c) do not differ significantly at P = 0.05

recorded biomass yield were BDN 711 in T_3 (4230.6 kg/ha) and T_1 (4644.1 kg/ha), BSMR 736 (5325.8 kg/ha) in 2011 as revealed in **Table 8** and **Fig. 3.**

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