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Are Indeterminate Genotypes More Productive Than Determinate Ones in Dolichos bean [*Lablab purpureus* (L.) Sweet]?: An Analysis based on Near Isogenic Lines Differing in Growth Habit

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ABSTRACT

Background: Determinate growth habit is farmer-preferred trait in dolichos bean. Fresh pods are harvestable and marketable economic products in dolichos bean. For ready acceptance of determinate cultivars, they should be in high fresh pod yielding background. Empirical evidence based on non-isogenic backgrounds indicated that genotypes with indeterminate growth habit produce greater fresh pod yield than those with determinate growth habit. However, confounding effects of the genes other than those controlling growth habit on fresh pod yield cannot be ruled out. Near isogenic lines (NILs) are ideal genetic resources to assess un-confounding effect of growth habit on fresh pod yield.

Methods: Six pairs of NILs differing for growth habit developed from heterogeneous inbred families (HIFs) of F2:5 recombinant inbred population were field-evaluated in two-replicated RCBD design at three locations for days to 50% flowering, number of fresh pods plant^{-1} and fresh pod yield plant^{-1}. Significance/other-wise of differences between determinate and indeterminate components of NILs were examined using two-sample 't' test with unequal variance.

Result: Indeterminate NILs were late to flower by one week and produced two-fold greater number of fresh pods and higher fresh pod yield compared to their determinate counterpart NILs. Given that NILs used in the present study differed only for loci controlling growth habit, we strongly believe that genes controlling growth habit perhaps have pleiotropic effects on number of fresh pods and fresh pod yield in dolichos bean. These results are discussed in relation to strategies to maximize fresh pod yield potential of determinate cultivars in dolichos bean.

Key words: Determinate, Growth habit, Heterogenous inbred families, Indeterminate, Near isogenic lines.

INTRODUCTION

Market-driven agricultural produce has necessitated Indian farmers to practice multiple cropping systems to enhance the net income per unit area and time. This together with acute shortage of human resources has forced farmers to adopt short duration crop cultivars which besides easily fit into multiple cropping systems, are most suitable for mechanized agriculture. Traditionally dolichos bean, one of the ancient grain legume crops grown extensively in India was being produced predominantly for subsistence consumption. However, owing to increasing demand, dolichos bean is now produced on a commercial scale for large scale consumption. Fresh pods are harvestable and marketable economic products in dolichos bean. Traditional cultivars which are highly photoperiod sensitive (PS) and exhibit indeterminate growth habit produce pods in non-synchronous manner. This results in staggered harvest of pods. Marketing of pods produced in staggered manner is uneconomical. This situation has forced farmers to switch over to adoption of determinate cultivars which are photo

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period insensitive (PIS) produce pods in synchronous manner and hence are also suitable for mechanical harvesting (Kim and Okubo 1995). Researchers from our laboratory namely Uday Kumar *et al.* (2017) and Chandrakant *et al.* (2018) reported comparable grain yield performance of short and medium duration determinate and indeterminate recombinant inbred lines (RILs) derived from cross between PIS determinate and PS indeterminate parents in dolichos bean. They also reported relatively greater grain yield potential of indeterminate RILs compared to determinate RILs of long duration. These reports though based on determinate and indeterminate genotypes of comparable genetic backgrounds differed with respect to genes controlling photoperiod sensitivity. Hence, confounding effects of photoperiod sensitivity genes on the impact of growth habit genes cannot be ruled out. Hence, the use of near isogenic lines (NILs) differing for growth habit but sharing common and PIS genetic background are most appropriate genetic resources for investigating the effects of growth habit genes non-target traits.

Researchers such as Curtis *et al.* (2000); Ellis *et al.* (2000); Cober and Morrison (2010) have reported effects of growth habit genes on grain yield and its component traits in soybean one of the grain legumes comparable to dolichos bean. Taking cues from these reports, we hypothesize that genes controlling growth habit have significant influence on non-target traits such as fresh pod yield and its component traits in dolichos bean as well. To empirically verify our hypothesis, we used six pairs of NILs differing for growth habit developed from heterogenous inbred families (HIFs) of F2:5 recombinant inbred (RI) population derived from PIS parents differing for growth habit and examined the effect of growth habit on fresh pod yield and its component traits in dolichos bean.

Table 1: List of HIF-derived six NILs and their pedigree.

NIL	Pedigree
1-D/1-ID	HA4/HA5-2020-F5-1-D/1-ID
6-D/6-ID	HA4/HA5-2020-F5-6-D/6-ID
22-D/22-ID	HA4/HA5-2020-F5-22-D/22-ID
67-D/67-ID	HA4/HA5-2020-F5-67-D/67-ID
25-D/125-ID	HA4/HA5-2020-F5-125-D/125-ID

MATERIALS AND METHODS

The material consisted of six pairs of near isogenic lines (NILs) differing for growth habit (Table 1). These six pairs of NILs along with their parents namely HA 4 (determinate and photoperiod insensitive) and HA 5 (indeterminate and photoperiod insensitive) were evaluated in three different locations-(i) experimental plot of GPB, CoA, UAS, Bangalore, (ii) Krishi Vigyana Kendra (KVK), Hadonahalli, Bangalore, India and (iii) farmer's field, Belagavi, Karnataka, India during 2023 summer season following randomized complete block design (RCBD) with two replications. Seeds of each component lines of six pairs of NILs were sown in a single row of 3 m length. 10 days after planting, seedlings were thinned to maintain recommended spacing of 0.3 m between the plants within a row. All the recommended production practices were followed to raise healthy plants and 8-10 plants survived to maturity in each pair of NIL.

Sampling of plants, data recording and statistical analysis

Data were recorded on five randomly selected plants from each component of pairs of NILs for days to 50% flowering, fresh pod number plant^{-1} and fresh pod yield plant^{-1} following descriptors (Byregowda *et al.,* 2015). Replication-wise trait means of determinate and indeterminate NILs were used for statistical analysis. Location-wise and pooled analysis of variance (ANOVA) of these traits was performed using R version 4.1.2. The six pairs of NILs differ only for growth habit and represent only miniscule of the entire genome. Hence, we hypothesize that any significant differences between the pairs of NILs for non-target traits are most likely due to the pleiotropic effect of genes controlling growth habit. To compare the differences between six pairs of NILs, (if any) for fresh pod number plant^{-1} and fresh pod yield plant^{-1}, we estimated Best Linear Unbiased Predictor (BLUP) of these traits by considering days to 50% flowering as a covariate to rule out its possible confounding effects. BLUPs were used to examine the significance of differences, if any between the six pairs of NILs for fresh pod number plant^{-1} and fresh pod yield plant^{-1} using two sample 't' test using unequal variances. Significance of 't' test was considered as evidence for pleiotropic effect of genes controlling growth habit on fresh pod number and fresh pod yield.

Table 2: Location-wise of variance of HIF-derived NIL pairs and their parents for different quantitative traits in dolichos bean.

	Df	Days to 50% flowering			Fresh pod number plant^{-1}			Fresh pod yield plant^{-1}		
		GKVK	Hadonahalli	Belagavi	GKVK	Hadonahalli	Belagavi	GKVK	Hadonahalli	Belagavi
Replication	01	3.40 ×10^{-28}	0.04	0.14	0.70	1.58	0.52	0.86	0.11	2.86
NILs	13	42.30**	41.60**	41.5**	483.00**	455.00**	466.00**	2352.00**	2398.00**	2561.00**
Residual	13	0.31	0.81	0.99	2.48	1.32	1.47	4.03	4.32	2.74

Df- Degrees of freedom, **Significance at P = 0.01.

RESULTS AND DISCUSSION

Analysis of variance

Location-wise (Table 2) and pooled (Table 3) analysis of variance indicated significant differences among all the pairs of NILs in each location for all the three traits under study. The performance of six pairs of NILs was comparable across locations, as indicated by the non-significant NIL × location interaction, suggesting predictability of the performance of NILs across test locations. These NILs differing for growth habit controlled by major genes (Keerthi *et al.,* 2014; Keerthi *et al.,* 2016; Basanagouda *et al.,* 2022) offer a common genetic and PIS background to assess unconfounded and unambiguous effect of growth habit on days to 50% flowering, fresh pod number plant^{-1} and fresh pod yield plant^{-1}.

Effect of growth habit on non-target traits

Both determinate and indeterminate components of NILs varied widely for all the three traits (Table 4). However, the extent of range with respect to days to 50 % flowering and fresh pod number plant^{-1} in indeterminate component lines of NILs was at least two folds greater than that in determinate component of NILs. The short growth period of determinate NILs could be attributed to breakage of shoot apical meristem (SAM) dominance (Krylova *et al.,* 2020; Li *et al.,* 2021). Our results are not surprising given that the duration of overlap between the vegetative and reproductive phases in indeterminate genotypes is longer than those in the determinate ones (Bernard 1972; Hartung *et al.,* 1981; Cober and Morrison 2010). Considering that differences in days to flowering between pairs of NILs are likely to confound the differences between them for other traits (Curtis *et al.,* 2000) such as fresh pod number plant^{-1} and fresh pod yield plant^{-1}, we used days to flowering as a covariate. The magnitude of range was three times greater in indeterminate component of NILs than that in determinate component of NILs for fresh pod yield plant^{-1}. On an average, indeterminate NILs were late to flower by seven days and produced greater fresh pods number plant^{-1} (Table 4, Fig 1) and fresh pod yield plant^{-1} than determinate NILs (Table 4, Fig 2). In soybean, Ablett *et al.* (1989); Robinson and Wilcox (1998); Kato *et al.* (2018) and Kato *et al.* (2019) have also reported significantly greater economic product (grain) yield in indeterminate genotypes than that in determinate ones. Our results suggest significant influence of growth habit genes for which NILs were selected on non-target traits such as those considered in the study. We believe that, substantial differences in days to 50% flowering, fresh pod number plant^{-1} and fresh pod yield plant^{-1} between determinate and indeterminate component genotypes of six pairs of NILs could be due to pleiotropic effects of growth habit genes in dolichos bean. However, the results need to be validated using a large number of NIL pairs differing for growth habit.

Table 3: Pooled analysis of variance of HIF-derived NIL pairs and their parents for for different quantitative traits in dolichos bean.

Source of variation	Days to 50% flowering				Fresh pod number plant^{-1}				Fresh pod yield plant^{-1}			
	Df	Mean sum of squares	F statistic	P value	Df	Mean sum of squares	F statistic	P value	Df	Mean sum of squares	F statistic	P value
Locations	02	0.46	6.63×10^{-1}	0.52	02	4.97	2.83	0.07	02	5.18	1.40	0.26
Replication (Locations)	03	0.06	8.50×10^{-2}	0.97	03	0.94	0.53	0.66	03	1.27	0.34	0.79
NILs	13	123.15	1.76×10^{2}	2.20×10^{-30}	13	1397.52	796.22	4.92×10^{-4}	13	7298.20	1973.69	1.07×10^{-50}
NILs × Locations	26	1.05	1.50	0.12	26	3.29	1.87	0.04	26	6.27	1.69	0.07
Residual	39	0.70			39	1.76			39	3.69		

Df- Degrees of freedom, **Significance at P = 0.01.

Table 4: Estimates of descriptive statistics for for different quantitative traits in within determinate and indeterminate NILs.

Traits	Determinate NILs		Mean	Indeterminate NILs		Mean
	Maximum	Minimum		Maximum	Minimum	
Days to 50% flowering	55.50	51.00	53.25	65.33	54.67	60.00
Fresh pod number plant^{-1}	27.41	18.77	23.09	55.62	35.08	45.35
Fresh pod yield plant^{-1}	62.77	40.59	51.68	129.35	60.47	94.91

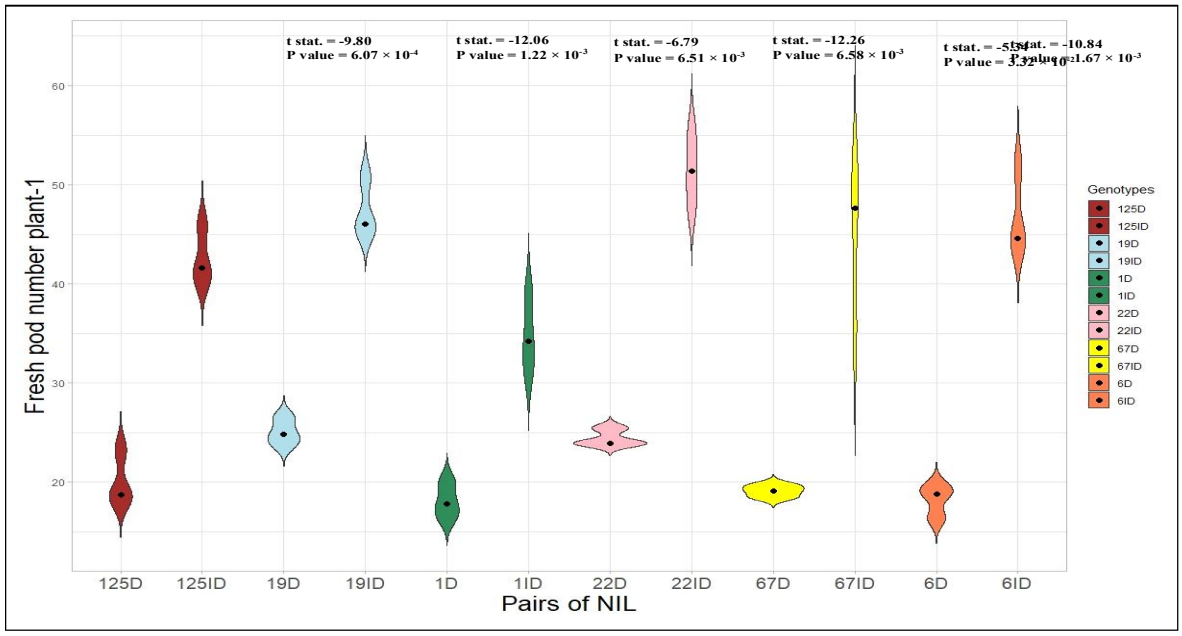


Fig 1: Violin plots depicting significant differences between six pairs of NILs for fresh pod number plant^{-1}.

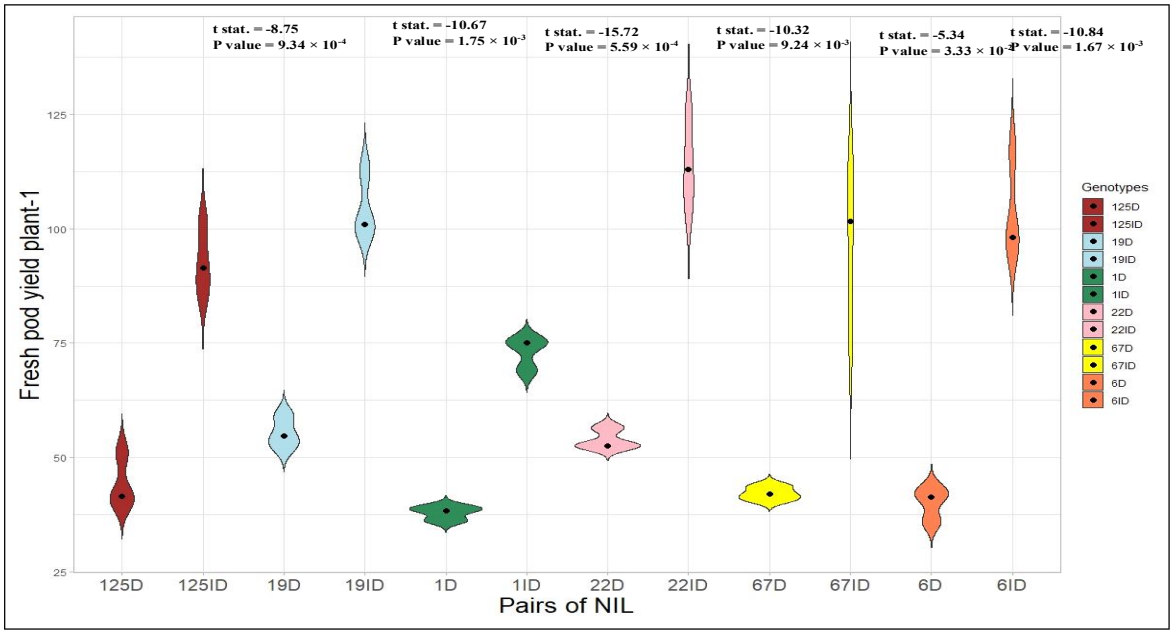


Fig 2 : Violin plots depicting significant differences between six pairs of NILs for fresh pod yield plant^{-1}.

Previous reports on pleiotropic effects of growth habit genes on grain yield and its component traits using NILs in a range of crops such as common bean (Wallace *et al.,* 1993) and soybean (Curtis *et al.,* 2000; Ellis *et al.,* 2000; Cober and Morrison 2010) and Barley (Kuczyńska *et al.* (2014), would lend adequate support to our belief. Hodgkin (2002) opined that pleiotropic genes are widely believed to be evolutionarily conserved as they are subjected to natural selection pressure acting on multiple traits. We believe that Hodgkin's (2002) opinion is relevant to genes controlling growth habit in dolichos bean, as growth habit is one of the evolutionarily shaped traits, which is associated with increased fitness under natural selection pressure.

CONCLUSION

Selection of determinate genotypes with fresh pod yield potential comparable to indeterminate ones is not likely to be effective as growth habit genes have pleiotropic effects. Perhaps, resources need to be focused towards developing determinate cultivars that require between 46-50 days to flowering from the date of planting considering narrow difference between fresh pod yield potential between determinate and indeterminate genotypes when determinate genotypes require 46-50 days to flowering. Further, by virtue of their short maturity period and compact growth habit, per day productivity as well as productivity *per se* of determinate cultivars could be maximized by high density planting.

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Ethical approval

This manuscript does not contain studies performed by any of the authors involving human or animals.

Consent to publication

All the authors have provided their consent for publication of this manuscript.

Conflict of interest

Author of this manuscript declare that we have no conflict of interest.

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