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INDICATION OF CURVILINEAR RELATIONSHIP BETWEEN SEED SIZE AND YIELD IN PIGEONPEA

Agricultural Science

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ABSTRACT

In pigeonpea [Cajanus cajan (L.) Millsp.], both seed size as well as yield are important from the viewpoints of profitability, marketing, and processing. Hence, an understanding of the nature of association between these two traits will be helpful in breeding new cultivars. In the present study this relationship was studied in 219 genotypes, and it was found negative but weak (r=-0.24**). A perusal of graph spread points revealed that this association, contrary to the expectations, was not linear. The seed yield increased nearly linear with increase in seed size until the latter approached to about 9 g/100 seeds. Similarly, beyond 13 g/100 seeds, the yield started diminishing gradually with further increases in seed size. This research, for the first time in pigeonpea, gave an indication of a curvilinear relationship between seed size and yield. Considering non-preference for small seeds in trade and nature of this relationship, it is emphasized that breeders focus on selecting medium size (9-13 g/100 seeds) grains while breeding new high yielding pigeonpea cultivars.

KEYWORDS

Cajanus cajan, high yield, market preference, milling recovery, non-linear correlation, seed siz

INTRODUCTION

Pigeonpea [Cajanus cajan (L.) Millsp.] is a popular pulse crop of rainfed agriculture and it is cultivated both under mixed as well as pure stands for its nutritive grains. In India, pigeonpea is grown on over 5.0 m ha (FAO, 2021) and it is used as food, fodder and feed, soil enrichment and fuel wood (Saxena et al., 2021). Since the entire pigeonpea produce of the country is milled and converted into dal (decorticated splits) for consumption, its seed size is important to minimize the milling losses. Therefore, for commercial survival of the crop both high yield and appropriate seed size hold the key.

Since there is a large variation (2.8 to 25.8 g/100 seeds) for seed size (Singh et al., 2014) in pigeonpea, the breeders have luxury of breeding cultivars with seed size of their choice. But the dilemma is that the large-seeded genotypes are low yielders and those with small grains are least preferred by traders and commercial millers. Hence, an appropriate balance between the two traits is essential for optimizing the returns from cultivating pigeonpea. Breeders, in general, have tendency to go for large-seeded individuals while exercising selections within breeding populations; and this may skew the balance at the cost of productivity. Therefore, to identify the thresholds, a good understanding of the relationship between yield and seed size is necessary; and the present study is a step forward in this endeavour.

MATERIALS AND METHODS

To conduct this experiment a total of 339 F5 medium maturing single plant progenies were sown in paired rows for evaluation under a pedigree-based varietal development programme at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). A basal doze of fertilizer @100 kg/ha DAP was applied and for good drainage ridges, 75 cm apart, were made along the slope. The seeding was done manually with inter-hills spacing of 30 cm. The crop was grown with irrigation under full plant protection to protect the crop from Helicoverpa armigera, the most destructive pod borer of pigeonpea.

In view of relatively less reliability of single plant yield data in breeding due to high genotype x micro-environment interaction in determining seed yield (Green et al., 1981), the yield data in this experiment were collected on plot basis and not on single plants. Therefore, at maturity, all the progenies were scored visually for their uniformity using 1(most uniform) - 5 (most variable) scale; and those scoring '1' and '2' were selected. A total of 219 plots were selected. Each plot was harvested excluding the border plants and yield was recorded after sun-drying the harvest for a week and threshing them using a 'Pullman' thresher. For recording seed size, from each plot five competitive plants were selected randomly and harvested separately. From each plant a sample of 100 seeds was taken using electronic seed counter and its weight recorded using an electronic balance. After this, the grains were added to the respective plot yields and their final weights recorded. To visualize the overall trend of the relationship between yield and seed size, a scatter diagram was prepared by plotting the yield data against seed size. Besides this, simple correlation coefficients were also estimated using the standard co-variance analysis.

RESULTS AND DISCUSSION

Results of the research conducted to elucidate the role of seed size in determining yield in different pulse crops in the past are inconsistent and vary with genotypes and environments. Smitchger and Weeden (2018) while reviewing the relationship of seed size with yield concluded that this relationship is complex and vary greatly across and within various pulse species. Gambin and Borras (2010) stated that yield within a species was more related to variations in seed number rather than in seed size.

In field pea (Pisum sativum L.), a positive relationship between seed size and yield was reported by Tawaha and Turk (2004), Bing and Liu (2011) and Kosev and Mikic (2012). According to Krajewski et al. (2012) this relationship in pea was positive but weak and explained only 20% variation in seed yield. In contrast, Timmermann-Vaughn et al. (2005) reported a negative association between seed size and yield. Interestingly, to predict a suitable ideotype for seed size in peas, Smitchger and Weeden (2018) simulated an algorithm equation and concluded that nearly all commercial pea varieties have large seeds and therefore produce less yields. They further opined that to maximize yields in pea, the new cultivars should be bred with seed size of around 12.5 g/100 seeds.

Gan et al. (2003) observed that chickpea (Cicer arietinum L.) the seed size had no significant impact on plant growth, development or seed yield. Biger (2009) reported a positive correlation between seed size and yield but with no effect on other yield components. Gan et al. (2006) deliberately selected small and large seeds in a given lot of an adapted chickpea variety for three succeeding generations. They reported 23% less yield in the small seeded selected bulk. On contrary in the large-seeded lot, a significant increase was recorded in biomass production but seed yield remained more or less the same. These observations suggested a positive relationship between seed size and yield only in small-seeded chickpea germplasm.

White and Gonzalez (1990) delineated a negative relationship between seed mass and grain yield in common bean (Phaseolus vulgaris L.). Wood et al. (1977) postulated that the larger seeds in this crop may increase grain yield only if the initial plant growth is sufficiently large or the key yield components are determined during early growth of the plants. Interestingly, Lima et al. (2005) opined that initial slower growth of the plants which emerged from small seeds could be counter-balanced by their delayed leaf senescence, increased net assimilation rate, and a greater number of seeds/ pods to produce yield similar to those originated from larger seeds. They concluded that larger seeds did not have any significant effect on yield but improved early plant growth, reduced number of seeds/ pods, increased 100-seed mass and reduced harvest index.

Pedersen (2006) reported that smaller and larger seeds separated from the same variety had similar yields in soybean (Glysine max L). Rifaee et al. (2004) observed that small seeds produce significantly better yield over a range of environments in faba beans (Vicia faba L). According to Biger (2009) and Gusmao et al. (2012) no significant relationship between seed size and yield existed in lentil (Lens culinaris Medik) and grass pea (Lathyrus sativus L.).

In case of pigeonpea, a vast variation (2.8 to 25.8 g/100 seeds) for seed size exists. For the sake of convenience, the germplasm is broadly divided into large (approx. ≥ 13 g/100 seeds), medium (>9 to <13 g/100 seeds) and small (approx. ≤ 9 g/100 seeds) groups. Each group has certain properties with respect to its plant type, adaptation, and productivity. The crop breeders, therefore, have option to assess the pros and cons of each group and then focus on a particular seed size for breeding new cultivars. The expression of seed size in pigeonpea is controlled by oligo-genes with additive gene action and high heritability (see review by Saxena and Sharma, 1990). For these good reasons, the desired seed size can easily be fixed while breeding inbred cultivars following simple selection procedures.

Research on the effects of seed size on growth and development in pigeonpea has been limited and most of it is centred around its influence on rate of germination, seedling vigour and yield. The large seeds, due to their more cotyledon reserves, give rise to vigorous seedlings; and this helps in initial establishment of crop and also in competing with weeds and companion crops. Narayana et al., (1981) opined that since in pigeonpea the germination is hypogeal, the large seeds have great advantage in the emergence of seedlings through the tough crusted soils.

In the studies conducted by Narayana et al. (1981) the seed size was found to be positively associated (r = 0.52**) with seedling dry matter but not with yield. Zavinon et al. (2019) also reported no correlation between seed size and yield in African pigeonpea genotypes. Similarly, Kandarkar et al. (2020) also recorded no association between these two traits in the pigeonpea germplasm of central India. In the present study the association between seed size and yield was studied in 219 genotypes representing 91 single crosses. The estimate of correlation coefficient across the genotypes was negative but weak (r = -0.24**) and accounted for only 5.8% of the total variation in yield. The scatter diagram (Fig.1a) of this data showed a broader picture of this relationship and revealed that the relationship between these two variables was not perfectly linear, and instead, indicated towards a curvilinear manifestation.

To confirm the hypothesis of curvilinear nature of correlation, the small-, medium- and large-seeded lots were studied separately. In the small-seeded group (n=65), where seed size ranged up to 9.0 g/100 seeds, the correlation coefficient was positive (r = 0.50**). The expanded graph of this seed sector (Fig 1b) further confirmed this observation. Similarly, in the large-seeded sector, despite being only 10 pairs of observations, both the correlation coefficient (r = -0.67**) and graphics (Fig 1d), showed a negative association trend between seed size and yield. At this point it should be noted that in this group the number of observations were limited; and therefore, need further confirmation. In the medium size lot (n=144) the relationship between these two variables (Fig 1c) was negative but quite weak (r = -0.15*).

A thorough envisions of the present results showed that the relationship between seed size and yield in pigeonpea was not strictly linear but acquired a wavy or curvilinear manifestation. The results also showed that up to a certain point (approx. 9 g/100 seeds) the seed yield increased with seed size. This type of observation was also recorded by Gan et al. (2006) in chickpea. In the medium- size group this correlation was negative but weak. But from another specific seed size threshold (approx.>13 g/100 seeds), the yields started declining with increases in seed size. In this group a negative trend (Fig 1d) was visible.

Based on the number of genotypes in different seed grades used in this study, someone may argue about the presence of curvilinear correlation between seed size and yield. In this context the authors feel that the number of entries in the small (65) and medium (144) groups is reasonably good. In the large-seeded group (10), however, this number is certainly small; but despite this limitation, a negative trend was clear with a percent reliability score (R2) of 46. In view of large variation in the germplasm for both seed size and yield, and to validate the assumption of curvilinear association, it is necessary that such studies are conducted with a greater number of diverse entries in different seed size groups.

A perusal of pigeonpea variety-production scenario shows that the large seeded vegetable type cultivars invariably have long pods (≥7 seeds/ pod) with few branches and a propensity to bear fewer pods on each plant; and this, finally ends up in producing fewer grains (Saxena et al., 2010 and 2017). In contrast, the commercial grain type cultivars have smaller pods with ≤ 6 seeds in each. These types, in general, have big canopy, more primary and secondary branches, large number of pods/ plant and small to medium size seeds. These types produce more grains than those of the bold seeded types.

Seed size in pigeonpea has important commercial significance with respect to its marketing and processing. To understand the choice of grainsize for efficient milling and high profits, Singh and Jambunathan (1981) surveyed 176 commercial dal mills in different parts of India. They concluded that majority (>80%) of the millers preferred medium to medium bold (approx. 10-15 g/100 seeds) round grains for high dal recovery, minimum processing losses and high-quality splits with sharp edges. In this seed size group, the relationship between the seed size and yield, though negative, is quite weak. Based on the present correlation study and millers' choice, it is suggested that the breeders should exploit the medium seed size window and avoid the temptation of selecting large-seeded genotypes while developing high yielding pigeonpea cultivars. This will benefit all - the farmers, traders, and millers.

A linear relationship between any two variables is straight forward and easy to comprehend. In contrast, the non-linear or curvilinear types of associations involve pattern(s) of changes (increase or decrease) which are linked to the value changes in the variable(s). This type of relationship is relatively more complex because its values may be different at different levels of variables; and this may easily influence the breeding values of selections. The plant breeders, therefore, should handle such relationships with care. It is also possible that sometimes breeders might overlook the existence of curvilinear relationship in their data set, and thus, may fail to spot any valuable or unique information they could have otherwise offered from their research.

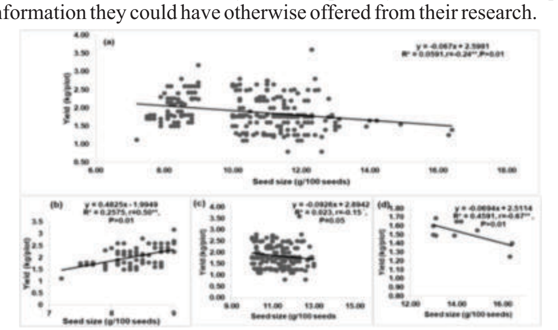

Figure 1: Relationship between seed size (g/100 seeds) and yield (kg/plot) (1a) overall (219) genotypes, (1b) small (1c) medium and (1d) large seeded groups of genotypes

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