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FABA BEAN CULTIVARS FERTILIZED WITH PHOSPHORUS ASSESSED FOR PRECISION AND BIAS OF YIELD ESTIMATION TECHNIQUES, AND FOR YIELD COMPONENT POWER AND SAMPLE SIZE

BY

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ABSTRACT

The choice of seed yield estimation technique--other than the middle 3-row sampling technique for faba bean (*Vicia faba* L.)-- relies greatly on amounts of bias and precision of such technique. Also, of concern to researchers is to determine sample size and statistical power to detect real treatment differences for yield components. This study aims at (i) assessing different faba bean seed yield estimation techniques for bias and precision, (ii) determining both sample size and power to detect differences among entry means for yield components, and (iii) studying faba bean cultivar response to phosphorus fertilizer rates. Four cultivars were fertilized with three phosphorus rates in three replicates in a split plot design in 2002 and 2003 in Moshtohor Experiment Center, Kalubia, Egypt. On per five (0.60 m x 3.5 m) row subplots, relative seed yields precision and bias of each of four sampling techniques were assessed relative to the commonly used middle 3-row sampling technique. These were (i) 1-row, (ii) 2-row, (iii) border rows + 10-cm end-row plants, and (iv) whole subplot. Results indicated that both 1-and 2-row sampling techniques showed no bias each the 3-row sampling technique and from each other. The 2-row, however, had a 2-yr average CV of 10.5% compared to 15% for the 1-row, but it showed little improvement in bias. Using sample size of n = 15 branches for plant height, and 45 for other yield components detected true treatment differences as small as 40% of treatment effects with power ranged from 0.50-0.99 in Year 1, and perfect power in Year 2. Sample size required to detect 0.80 power was in the range of 3-10 branches character wise. None of yield component characters and total seed yield significantly differed for both cultivar and cultivar x phosphorus rate interaction in both years. Applying 31.0 kg fa $^{-1}$ P_2O_5 resulted in 32% in 2002, and in 18% more total seed yield in 2003 relative to a 15.5 kg fa $^{-1}$ P_2O_5. But, seed yield changed upward just by 11% in Year1 and by 4% in Year2 by increasing rate to 46.5 kg.

Key words: *Vicia faba* L., Faba Bean seed yield, Cultivars, Phosphorus, Precision, Bias, Power, Sample Size.

INTRODUCTION

In field trials, particularly row- or ridge-seeded crops, e.g. faba bean, and soybean *Glycine max* (L.) Merr., seed yield estimation is usually based on plant yield taken from all middle rows after removal border rows prior to harvest. If precision and bias, of seed yield estimates based on other sampling techniques compared to the middle row sampling technique, prove tolerable and acceptable, this would help reduce resource costs--seeds, time, and labor. Hunt *et al.* (1987) found in soybeans that shoot dry matter estimated from a 1-m section of a row was not significantly biased from the trimmed subplot sampling technique and had an acceptable precision (CV < 24%).

Although end trimming plots prior to harvest is time-consuming and labor demanding, it eliminates the tendency of row-end plants to inflate entry relative yields (Meis *et al.*, 2002). This is because these end-row plants compete much less for light, nutrients, and water. Boerma *et al.* (1976) found that when plots were not end-trimmed at maturity, soybean genotype relative yields changed. However, Philbrook and Oplinger (1988) reported unaffected relative yields of soybean genotypes by end-trimming in two of three years, but in one season, time of this process influenced relative yield performance. Based on the above results, there has been no consistent evidence that supports or rejects end-trimming field plots (Meis *et al.*, 2002). Therefore, resources devoted to end trimming at harvest, as they argued, could be allocated to other aspects of genotype evaluation if reasonable accuracy of selection can be maintained.

Another field plot technique of concern to researchers is deciding on the minimum sample size needed to estimate yield components to maintain quite reasonable power--probability of rejecting a false null hypothesis. Increasing sample size or the amount of replication (number of replicates, samples within plots) as Casler and Ehlke (1985) pointed out improves precision (low variance) but increases costs. The sample size required for an α-level least significant difference (LSD) positively correlates with i) power (Gatti and Harwell, 1998), ii) differences among entry means, iii) fewer number of entries, but negatively relates to estimated error variance (Zar, 1984).

Phosphorus fertilizer effect on faba bean has been extensively studied. Both 15.0 and 30.0 kg P_2O_5 fa^{-1} did not affect plant height, branch $plant^{-1}$, pod $plant^{-1}$, seed $plant^{-1}$, and seed weight $plant^{-1}$; but seed index and seed yield fa^{-1} increased only in one year (Allam, 1993). In another study on Faba bean Giza 2 cv by Tageldin and Abdullah (1997), there was a linear increase in total seed yield using 15.5 and 31.0 kg fa^{-1} P_2O_5 and a control.

This study has three-fold objectives to i) assess different seed yield estimation techniques based on plot yield data, and investigate whether trimming plots inflates seed yield; ii) determine both sample size and power needed to detect difference among faba bean entry means; (iii) study faba bean cultivar response to phosphorus fertilizer rates.

MATERIALS AND METHODS

A two-year field study was conducted at the Moshtohor Research Center, Kalubia, Egypt in 2002 and 2003 on a clay soil with a pH of 7.8 and organic matter content 18 g kg^{-1}. Available P content in the soil was about 11 mg kg^{-1}. The experimental area was divided into 3.0 m x 3.5 m subplots, each had five rows 0.60m-apart. Two seeds of each of four faba bean (*Vicia faba* L.) cultivars were planted in hills 10 cm-apart on one side of each row on 11 and 15 November in 2002 and 2003, respectively; this makes 33 seeds m^{-2} to have nearly a total plant population of 140,000 plants fa^{-1}. Cultivars were Giza 3, Giza 40, Giza 716, and Nubaria 1. Each cultivar was fertilized with 15.5, 31.0 and 46.5 kg P_2O_5. The P_2O_5 rates were applied, in the form of calcium mono superphosphate (15.5% P_2O_5) fertilizer, at planting. A split plot design was used where cultivars were in the whole plots and the P_2O_5 rates were in the subplots. Each treatment was replicated three times.

Harvesting was carried out during the third week of May in both seasons. At harvest, five random guarded plants from each subplot were harvested to estimate plant height, branch number $plant^{-1}$, pods $plant^{-1}$, seed weight $plant^{-1}$, and 100-seed weight. Plant height was measured only from the five main stems of each random sample; this makes a total of 15 stems per sample (5 main stems x 3 replicates). For the above yield components, each plant, on the average, had 3 branches, which makes a total of 15 branches per replicate, and 45 branches per the three replicates to estimate each character. Hence, sample size, n, equals rep x plants for plant height, and equals rep x plants x branch $plant^{-1}$ for yield components.

Bias and Precision of Sampling Techniques

Seed yield (kg fa^{-1}) was estimated using four methods for each subplot, in addition to the whole 10.5 m^2 subplot. At harvest, a one-hill row end plants (10 cm) was end trimmed from both sides of each of the inner three rows of each subplot making a total length of approximately 3.30 m rows. This in addition to the outer two rows comprises the border portion of each subplot. Seed yield, therefore was estimated from: (1) one end-trimmed row, (2) the other two end-trimmed rows, (3) the total of the three rows, (4) border portion of subplots, and (5) whole subplot.

Since in field crop trials, researchers often estimate crop yield from the inner end-trimmed area (guarded plants), we relatively compared all sampling techniques to the 3-row technique. Therefore, variations of sampling method within subplots ($\hat{\sigma}_S$) (Hunt *et al.*, 1987) were directly estimated from the 36 differences:

$$d_s = \hat{X}_s - X, \quad (1)$$

Where: X = dry seed yield directly measured by harvesting the inner 3 rows; and $\hat{X}_s$ = the estimate of X based on sampling method (S), i.e. methods (1), (2), (4), and (5). The 36 differences were indexed by i, i = 1, ..., 36 (i.e. d_{Si}), and the bias of methods was estimated as the mean difference:

$$bias = \bar{d}_s = \frac{1}{36}\sum_{i=1}^{36} d_{si} \qquad (2)$$

Within subplot sampling variances of methods can be estimated as

$$\hat{\sigma}^2{}_s = \frac{\sum_{i=1}^{36}(d_{si} - \bar{d}_s)^2}{35} \qquad (3)$$

Since bias was computed relative to the 3-row technique, we hypothesized its within-plot variance ($\hat{\sigma}^2{}_s$) be equal to zero.

Sample Size and Statistical Power

Based on estimates of the variances ($\hat{\sigma}^2{}_e$) [mean square (replicates x P_2O_5 rates)/cultivars], the sample size (n = r x plants x branches plant^{-1}) required for a 5% least significant difference (LSD) with 80% power was computed (Steel and Torrie, 1980 and Casler and Ehlke, 1985) by

$$n = 2\,(t_{\alpha/2, df_e} + t_{\beta, df_e})^2\, \hat{\sigma}^2{}_e / d^2 \qquad (4)$$

where $t_{\alpha/2, df_e}, t_{\beta, df_e}$ are student's t-values for a 5% ($\alpha/2$ = 0.025) type I error rate and 0, 20% type II error rate (power = 1 – β = 80%) with 16 (4x2x2) degrees of freedom, *d* is the true difference between cultivars x P_2O_5 rate means desired for significance (Steel and Torrie, 1980), and *n* is the total number of observations required (rpt). Values of *d* used in computations were based on percentages of treatment effects

$$\alpha^2{}_i = (\bar{X}_{i.} - \bar{X}_{..})^2$$

where: $\alpha_i = \mu_i - \mu$, μ_i is the estimated mean of the ith treatment, and μ is the grand mean (Gatti and Harwell, 1998). For the same values of d, the power (the probability of rejecting a false null hypothesis) of the 5% LSD was also computed for the sample sizes (rp = 15 for plant height, and rpt = 45 for the rest of yield components) used in this study, by computing

$$\lambda = \sum_i \frac{\alpha^2{}_i}{\sigma^2{}_e / n} \qquad (5)$$

where: λ is a noncentrality parameter, which reflects the magnitude of the treatment effects, then

$$\phi = \sqrt{\lambda / t} \qquad (6)$$

Entering values of degrees of freedom for CV x P_2O_5 as V_1 and of error as V_2, α, and θ to the person and Hartley charts (Pearson and Hartley, 1951) to calculate power (1-β).

RESULTS AND DISCUSSION

Precision and Bias of Various Sampling Techniques

Criteria for reliable yield estimation technique(s) are i) less bias, ii) minimal REMS, iii) low CV, iv) tolerable costs. All seed yield sampling techniques showed consistency in differences ($p<0.05$) among replicates, and phosphorus (P) rates in 2002, and in cultivars (cv) in 2003 (Table 1). They also exhibited negligible variations ($p>0.05$) among cultivars in 2002 and P x cultivars interactions in 2003. However, each of 1-row, and border techniques gave P values > these of the 3-row, 2-row, and the whole plot in 2002 and 2003 (Table 1) for each of cultivars and P x cultivars interactions.

Hunt *et al.* (1987) pointed out that the inability to detect treatment differences is caused mainly by large experimental error as well as poor precision. This is evident in Table 2 where measures of precision are presented. The CV values for means obtained from sampling 1-row and border plants were quite higher (23.3% and 19.6%) compared to those of the 3-row, 2-row, and the whole plot (14.7%, 15.5%, and 13.1%) (Table 2). Similar trend was clear in 2003 (Table 2). The root error mean square (REMS) for the 1-row and the border were higher than the REMS for the 3-row, 2-row, and the whole subplot in the 2 years. These relatively high REMS values associated with the 1-row technique indicate high experimental error (plot to plot variation), i.e. high variation in row lengths from a subplot to another due to difficulty in keeping length as consistent as possible. Following end-trimming these rows at harvest, this may contribute more to this variability since removal of more than 1-hill plants would adversely influence total row seed yield. Also, any errors in keeping hill number nearly constant from row to row would also negatively affect row yield. For the border portion, it is more likely to get more seeds during planting or scattered seeds from neighbor plots. Also, more plant loss is expected due to breakage throughout the growing season. Along the middle three rows on both sides, severe trimming of end-row plants would affect border seed yield.

Mean seed yield (kg fa^{-1}), estimated from each of 1-row, 2-row, as well as of whole subplot, were close compared to that of the 3-row in both years (Table 2). In addition, estimated yield from 1-, and 2-row techniques were nearly equal in both years, but the 2-row had half as much bias standard deviation $\hat{\sigma}_s$ in both years. The estimated $\hat{\sigma}_s$ values for the whole subplot were unexpectedly low (59.357 and 20.052 kg fa^{-1}) in both years. On the other hand, estimated yield from border portion was relatively different in the tow opposite sides in both years, since in 2002 it underestimated seed yield and in 2003 overestimated it. Bias standard deviation $\hat{\sigma}_s$ in both years (192.771 and 144.173 kg fa^{-1}) still much higher compared to any other technique.

Bias measurements (Eq [2] and t-test) between different techniques in 2002 and 2003 are presented in Table 3. Seed yield bias between 1-row and 3-row, between 2-row and 3-row were small as were measurements of bias between 1-row and 2-row, and 1-row and whole subplot techniques in 2002 (Table 3). However, the latter bias was high only in 2003 (Table 3). In a soybeans

Table 1. Analysis of variance of faba bean seed yield as determined with data from various estimation techniques in 2002and 2003.

Source	df	Estimation techniques									
		3-row+		1-row		2-row		Border		Whole subplot	
		MS	p-value#	MS	p-value	MS	p-value	MS	p-value	MS	p-value
2002											
Replicate (R)	2	161917.2	0.0045	25366.3	0.0182	125326.4	0.0184	112138.8	0.0426	142582.2	0.0019
Cultivar (CV)	3	42205.7	0.1535	49170.6	0.4147	40462.1	0.2129	22819.9	0.5183	20559.6	0.2884
R x CV	6	132676.2	0.0015	141055.2	0.0418	145590.4	0.0019	128631.4	0.0079	140558.1	0.0002
Phosphorus (P)	2	227923.4	0.0011	245185.3	0.0202	219814.2	0.0023	196881.2	0.0073	176757.8	0.0007
P x CV	6	30944.6	0.2496	40919.8	0.5578	30955.7	0.3210	17691.4	0.7188	29408.2	0.1328
Error (b)	16	21026.3	-	48764.0	-	24199.4	-	28977.9	-	15034.05	-
2003											
Replicate (R)	2	87027.0	0.0001	19647.9	0.1201	166366.2	0.0001	135446.9	0.0005	102396.2	0.0001
Cultivar (CV)	3	42503.9	0.0001	39320.9	0.0137	82489.9	0.0001	46713.1	0.0189	49305.3	0.0001
R x CV	6	109585.9	0.0001	7778.3	0.0001	132855.0	0.0001	235594.7	0.0001	105226.6	0.0001
Phosphorus(P)	2	154896.3	0.0001	201905.5	0.0001	135229.5	0.0001	78059.6	0.0053	130495.8	0.0001
P x CV	6	2538.9	0.5819	4880.8	0.7243	3701.8	0.6216	4196.1	0.8693	2506.0	0.5870
Error (b)	16	3161.9	-	8094.9	-	4966.0	-	10534.7	-	3150.6	-

\+ 3-row = 10-cm end-trimmed middle 3 rows, 1-row = 10-cm end-trimmed single row, 2-row = 10-cm end-trimmed 2 adjacent rows, Border = plants of the 2 border rows + 10-cm end trimmed plants of the middle 3 rows, whole subplot = no-trimmed plot, MS = mean square.

\# p-value = probability of a greater F value under Ho.

experiment, bias measurements between the 0.3-m 4-plant sample techniques were small as bias between the 1-m and entire subplot-measured techniques (Hunt *et al.*, 1987). Also, Hanway and Weber (1971) reported overestimation for samples of 0.6- and 0.3-m row length. Although in the current study mean seed yield (kg fa^{-1}) from either the 1-row or 2-row sample techniques was close to each other as to that of the 3-row, each one significantly overestimated the whole subplot in both years (Table 2) except for a non-significant bias for the 1-row vs. whole subplot in 2002.

The tendency of small subplot sampling techniques to be biased upward exists as indicated by Hunt *et al.* (1987) even if plant population has been waived as a factor that may influence this bias. They argued that this overestimation was present in both years and with different individual samples even though their procedure incorporated random selection of samples.

Therefore, since both the 1-row and 2-row techniques were not significantly biased from the 3-row and from each other in both years by the t-test, they seem to be acceptable sampling techniques for estimation of faba bean seed yield. The 2-row technique, however, had a 2-yr average CV of about 10.5% vs. about 15% for the 1-row technique; a 2-yr average R^2 of 0.89 vs. 0.81 for the 1-row (Table 2). It appears that the 2-row technique is an acceptable sampling technique for faba seed yield. It improved precision, but it had little improvement in bias compared to the 1-row technique.

Table 2: Means and estimates of error by five estimation techniques of faba bean seed yield in 2002 and 2003.

Technique	Mean (Kg fa^{-1})	REMS⁺ (Kg fa^{-1})	CV %	R^2	$\hat{\sigma}_S$ # (Kg fa^{-1})
2002					
3-row	980.648	145.004	14.78	0.848	-
1-row	944.021	220.825	23.39	0.741	128.321
2-row	998.490	155.561	15.39	0.828	64.142
Border	866.277	170.229	19.65	0.771	192.771
Whole subplot	933.066	122.613	13.14	0.877	59.357
2003					
3-row	1270.891	56.231	4.42	0.962	-
1-row	1274.131	89.971	7.06	0.890	114.201
2-row	1268.672	70.470	5.55	0.954	57.037
Border	1552.806	102.638	6.60	0.922	144.173
Whole subplot	1197.777	56.130	4.68	0.961	20.052

+ REMS = root error mean square, CV = coefficient of variation, R^2 = multiple coefficient of determination.

\# $\hat{\sigma}_s$ = derived from Eq[3].

Table 3 . Measures of bias among various estimation techniques of faba bean seed yield in 2002 and 2003.

Statistic#	Estimation technique comparisons+						
	1r-3r	2r-3r	Brdr-3r	wp-3r	1r-2r	1r-wp	2r-wp
				2002			
Estimate of bias	-36.60	17.80	-114.30	-47.5	-54.5	10.90	65.40
SE of bias	21.38	10.14	32.12	9.89	32.07	25.42	12.90
t-test	1.71	1.76	3.56*	4.81*	1.69	0.43	5.07*
				2003			
Estimate of bias	3.2	-2.2	281.9	-73.1	5.5	76.4	70.9
SE of bias	19.033	9.506	24.028	3.342	28.539	21.970	6.849
t-test	0.170	0.233	11.732*	21.876*	0.191	3.475*	10.350*

\+ 1r-3r = 1 row – 3 row, 2r-3r = 2 row – 3 row, Brdr-3r = border – 3 row, wp-3r = whole subplot – 3 row, 1r-2r = 1 row – 2 row, 1r-wp = 1 row – whole subplot, 2r-wp = 2 row – whole subplot.

\# Estimate of bias = mean of the paired difference, SE of bias = square root of $(\hat{\sigma}^2_s)\,n^{-1}$, where n = 36, t-test compared to $t_{.025,35} = 2.021$.

Sample Size and Statistical Power

The phosphorus by cultivar interaction means for faba bean yield components were close in the 2 years for any particular character and so were the square roots of treatment effects ($\sum_i \alpha_i^2$) (Table 4). However, the CV values ranged from about 6 to 21% in 2002 and dropped severely in 2003 to range from about 2 to 8%. This was primarily a function of the root mean square error for each character in 2003. The values of root mean square error in 2003 relatively dropped by a range of approximately 2 to 7 folds compared to values in 2002 (data not shown).

The estimated powers, at true difference among P x CV means d = 20% of root mean square variation, were fairly low except for pods per plant, pod weight per plant and seed weight per plant in 2002 (Table 4). Power was in the range of 14 to 27% for plant height, branches per plant, and seeds number per pod, but it ranged from 64 to 73% for the other characters. But at d = 40% of root mean square variation, power ranged from 60 to 99%: 50% for seed index, 62% for plant height, and >86% for all other characters. This means that true differences of 5.6 cm in plant height and 3.8 g in seed index could not be detected with satisfactory values of power, but a variation of 0.3 branch per plant, 2 pods per plant, 10.6 g for pod weight per plant, 0.27 seeds per pod, and 8.0 g for seed weight per plant could be detected with more than 80% power. True differences at 60% of d or greater could be detected for all characters since power ranged from 88% for seed index to 100% for most characters at d = 100% in 2002 (Table 4). In year 2003, except for branches per plant and seeds per pod, power reached 100% at d = 20% (Table 4). From d = 40 to 100%, power values were mostly 100%.

Table 4. The 2002 and 2003 sample statistics, estimated power for detecting a true difference of size d between PxCV means (for n = rp = 15 for plant height, n = r x p x t = 45 for yield components). Sample size n required for 80% power.

Statistic	Faba bean yield component													
	Plant ht.		Branch pl^{-1}		Pod pl^{-1}		Pod $wt.pl^{-1}$		Seed pod^{-1}		Seed $wt.pl^{-1}$		Seed index	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Mean	77.3	107.4	2.90	2.90	15.80	15.60	43.50	40.80	3.20	3.30	31.50	31.10	70.10	73.60
$(\Sigma_i a^2_i)^{1/2}$+	14.05	14.62	0.71	0.58	5.15	5.40	26.53	10.81	0.67	0.34	20.16	11.29	9.56	7.15
Estimated power for detecting true difference for n														
d(% of $(\Sigma a^2_i)^{1/2}$														
20	0.17	0.97	0.27	0.54	0.64	0.99	0.69	1.00	0.27	0.61	0.73	1.00	0.14	0.99
40	0.62	1.00	0.86	0.99	0.99	1.00	0.99	1.00	0.86	0.99	0.99	1.00	0.50	1.00
60	0.95	1.00	0.99	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.88	1.00
80	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00
100	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
Sample size (n) required for 80% power														
20	104	10	184	90	74	10	67	9	186	79	63	9	392	17
40	26	3	46	22	18	2	16	2	46	20	15	2	98	4
60	11	1	20	10	8	1	7	1	20	9	7	1	43	2
80	10	0.6	11	5	4	0.6	4	0.5	11	5	4	0.6	24	1
100	5	0.4	8	4	3	0.4	3	0.3	8	3	3	0.3	16	0.7
CV%	5.8	1.8	13.6	7.6	11.4	4.5	20.4	3.3	11.6	3.9	20.9	4.5	11.0	1.7

+ $(\Sigma_i a^2_i)^{1/2}$ = Square root of treatment effect

Based on the power of significance tests in the 2 years of the study, it seems that using a sample size n = 15 branches for plant height or 45 for other yield components is more than enough to detect true differences at d > 40% of the root mean square variance of entry means. The non-centrality parameter λ, as has been indicated earlier is positively correlated to power, as it is to treatment effect a_i; yet it is negatively correlated to σ^2/n. In both years, the high power values obtained for all characters were mostly affected by the relatively high treatment effects as indicated in Tables 4. In year 2003 in particular, residual mean square estimates were quite low this led to high λ values.

To obtain 80% power for detecting a difference of only 1.9 g of seed index (20% of 9.562), would require a minimum of n = rpt = 392 observations per treatment in 2002(Table 4). In year 2003, 90 branches were needed to detect a difference of only 0.12 branches per plant. For all yield component characters a total sample size as small as 3 branches for pods per plant, pod weight per plant, and seed weight per plant; and as big as 16 branches for seed index were needed to obtain 80% power (Table 4). Sample sizes obtained in year 2003 (Table 4) were unrealistic at d > 60%. These low sample size values were mainly due to the low values of estimated error variance σ_e^2 obtained in year 2003.

In general, on deciding a required future power, a researcher should determine before hand the amount of true difference needed to detect for a particular character, sample size (s), an estimate of error variance based on historic data, number of treatments to be compared, and even as indicated by Gatti and Harwell (1998) different nominal type I error rates, For entry means, which exhibit very narrow variations about grand mean or range among these means as what Casler and Ehlke (1985) used, it is unrealistic to use a true difference, d, in the order of 20 to 40% of either treatment effect or range since this would lead to very low percentage power. The choice of sample size or replication (number of replicates, sample within plots, etc.) increases costs, but improves precision. Resource allocation (Carter *et al.*, 1983) between sample size per plot and plot replication per treatment should be considered if plant-to-plant and/or branch-to-branch variation within plants were more important compared to experimental error, emphasis, hence, should be placed on sampling as many random branches per plant as possible and minimal replication (Casler and Ehlke, 1985). However, they also pointed out that if experimental error were important, then failure to replicate plots would lead to increased type I error rate due to under-estimation of experimental error. Finally, α- and β-level are inversely related, and this would certainly affect power (1-β).

Yield Components and Seed Yield

Means for faba been yield components and total seed yield for cultivars, phosphorus rate, and interactions are presented in Table 5. None of yield component characters and total seed yield significantly differed ($p<0.05$) for both cultivar and cultivar x phosphorus rate interaction in both years. Cultivar total seed yield range, however, was quite great to not be statistically detected by F-test in both years; ranges were 167 and 162 kg fa^{-1} in 2002 and 2003, respectively. Cultivar rank, in addition, changed over years, since in 2002, Giza 3 cv ranked first, but third in 2003; Nubaria-1cv ranked last in 2002, but first in 2003. In general, averaged over phosphorus rates, cultivar total seed yield has dropped by about 29% (980.6 vs. 1270.9 kg fa^{-1}) in 2002 compared to 2003.

In both years, main plot coefficients of variation, CV%, were 21% and 15% (data not shown), which seemed quite reasonable values. However, in ANOVA tables, values for mean square for cultivar x block --error term for cultivars---were reasonably high (p<0.001) in both years. This resulted in a less sensitive test statistic to detect any true cultivar seed yield differences. Across years, any particular yield component character did not vary too much among cultivars to seem to have caused the shift that happened in cultivar mean total seed yield. Any variation in final cultivar plant population may explain the obtained shift in cultivar ranking. In 2002, though non significant, both per plant pod and seed weight were the only two yield component characters to have shown a relatively wide ranges as high as 12 g and 8 g, respectively, among cultivars, and to have exhibited similar ranks as of total seed yield (Table 5). Mean cultivar plant height was the only character that changed between years; it decreased by a 30-cm margin (77.3 cm vs. 107.4 cm) in 2002 compared to 2003. This reduction may explain the relative 29% drop in total seed yield.

Many studies have investigated phosphorus fertilizer in faba bean (Allam, 1993; Hussein *et al.*, 1993; Majumdar *et al.*, 1994; Tageldin and Abdullah, 1997). Applying 31.0 kg fa^{-1} P_2O_5 resulted in 32% in 2002, and in 18% more total seed yield relative to a 15.5 kg fa^{-1} P_2O_5 in 2003 (Table 5). But, seed yield changed upward just by 11% in Year1 and by 4% in Year2 by increasing rate to 46.5 kg. The fore mentioned yield component characters contributed in the same pattern to the relative change in total seed yield in both years since the rank of the three P_2O_5 was quite similar for each individual character over years (Table 5). Decreasing flower shed in faba bean --reflected in high pod number per plant-- has lately proven influential character to breed for more than improving seed index.

Though mean yield component characters and total seed yield for phosphorus rates across years were in the same range for any particular character, the $LSD_{0.05}$ values were quite lower in 2003 than in 2002. This as has been shown earlier was mainly due to the quite lower mean square error values in 2003. This resulted in more sensitive tests in 2003 to detect a little true difference between treatment means at the 5% significance level. The cultivar by replicate mean square was lower in 2003 for seed yield. In both years, ranges for total seed yield for cultivars were very close, 167 kg fa^{-1} in 2002 and 162 kg fa^{-1} in 2003, however, test sensitivity did not have any impact on detecting differences in studied cultivar means unless these differences really exist. Sampling a wide range of cultivar pool seems necessary in future studies.

Table 5: The 2002 and 2003 mean yield components and seed yield for faba bean cultivars, phosphorus fertilizer and interactions.

Treatment	Plant ht. cm	Branch pl^{-1}	Pod pl^{-1}	Pod wt. pl^{-1}, g	Seed pod^{-1}	Seed wt.pl^{-1}, g	Seed index	Seed yield kg fa^{-1}
2002								
Cultivar (CV)								
Giza 3	77.4	2.8	15.3	51.3	3.1	37.0	73.9	1060.57
Giza 40	82.4	29.	16.3	41.4	3.4	31.0	69.3	984.45
Giza 716	75.4	2.8	16.1	39.7	3.3	28.9	68.6	984.37
Nubaraia 1	74.0	3.1	15.8	41.6	3.1	29.1	69.0	893.17
LSD 0.05	NS	NS	NS	NS	NS	NS	NS	NS
Phosphorus								
15.5	77.3	2.9	14.3	36.3	3.2	26.0	69.4	834.67
31.0	79.9	2.9	17.5	48.7	3.3	35.7	71.5	1108.51
46.5	79.9	2.8	15.8	45.6	3.2	32.8	69.7	998.75
LSD 0.05	NS	NS	1.57	7.71	NS	5.70	NS	125.497
CV x P	NS	NS	NS	NS	NS	NS	NS	NS
2003								
Cultivar (CV)								
Giza 3	107.4	3.1	15.7	40.9	3.2	30.8	75.8	1262.07
Giza 40	111.4	2.9	15.5	39.7	3.3	29.2	71.9	1300.40
Giza 716	103.2	2.9	16.1	41.1	3.4	31.4	73.9	1179.90
Nubaraia 1	107.6	3.0	15.3	41.5	3.3	33.3	73.0	1341.17
LSD 0.05	NS	NS	NS	NS	NS	NS	NS	NS
Phosphorus								
15.5	103.6	2.8	13.6	36.6	3.2	27.2	71.7	1142.09
31.0	110.8	3.1	17.1	42.9	3.3	33.2	74.5	1356.90
46.5	108.0	3.0	16.4	42.9	3.4	33.2	74.7	1313.66
LSD 0.05	1.66	0.19	0.61	1.17	0.11	1.21	1.06	34.411
CV x P	NS	NS	NS	NS	NS	NS	NS	NS

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تقييم الدقة والتحيز لطرق معاينة مختلفة لتقدير محصول بذور أصناف الفول البلدي المسمدة بالفوسفور، وقوة الاختبار وحجم العينة لمكونات المحصول

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يعتمد اختيار طريقة أخري لتقدير محصول البذور في الفول البلدي عن الطريقة المعتادة وهى الثلاث خطوط الوسطى من القطعة التجريبية على مقدار كل من الدقة والتحيز. كذلك من الأمور التى تهم الباحث تحديد حجم العينة لتقدير صفات المحصول ومقدار قوة الاختبار لرصد فروق حقيقية بين متوسطات المعاملات. تهدف هذه الدراسة إلى (١) تقييم طرق معاينة مختلفة لتقدير محصول بذور الفول البلدي من حيث الدقة والتحيز، (٢) تحديد حجم العينة المناسبة وقوة الاختبار لرصد فروق حقيقية بين متوسطات المعاملات لصفات المحصول، و (٣) دراسة تأثر محصول بذور

ومكونـــات المحصـــول لأربـــع أصـــناف من الفول البلدي بثلاث معدلات من التسميد الفوسفاتي. في عامي ٢٠٠٢، ٢٠٠٣ تم زراعة أربعة أصناف من الفول البلدي—جيزة ٣، جـــيزة ٤٠، جـــيزة ٧١٦، و نوباريـــة ١. وســـمد كل منهن بثلاث مستويات من الفوســـفور— ١٥,٥، ٣١,٠، و ٤٦,٥ كجم فو٢أ٥ للفدان. وذلك في ثلاث قطاعات في تصـــميم قطـــع منشقة مرة واحدة في محطة تجارب كلية زراعة مشتهر - قليوبية - مصر.

تـــم تقدير الدقة والتحيز لكل من أربع طرق معاينة نسبة إلى طريقة المعاينة المعـــتادة وهـــي الثلاث خطوط الوسطى من القطعة التجريبية و ذلك عقب ازالة نبات واحـــد من نهايتي الخطوط وهم (١) خط واحد (٢) خطان، (٣) الخطوط الخارجية + نباتات نهاية الخطوط الوسطى، (٤) القطعة كلها.

كانت كل من طريقتي الخط الواحد والخطين غير متحيزتين معنويا نسبة إلى الـــثلاث خطوط وكذلك عن بعضهما. وكانت طريقة الخطين أكثر دقة من طريقة الخط الواحـــد حيث كان متوسط معامل الاختلاف ١٠,٥% مقابل ١٥% ولكن مقدار التحيز كان أقل قليلا. بالإضافة إلى ذلك، فإن استخدام ١٥ ساق رئيسي لتقدير طول النبات، و ٤٥ فرع لبقية صفات المحصول أدى إلى إدراك فروق بين المعاملات تصل إلى ٤٠% من قيمة تأثير المعاملات وذلك بقوة إختبار بين ٠,٥٠-٠,٩٩ في الموسم الأول وتصل إلـــى الواحد الصحيح في الموسم الثاني. كان حجم العينة المطلوب للوصول إلى ٠,٨٠ قـــوة اختبار في حدود ٣-١٦ فرع على مستوى جميع مكونات المحصول. أما بالنسبة آلـــي تأثير أصناف الفول البلدي و معدلات التسميد الفوسفاتي علي محصول البذور و مكونـــات المحصـــول، فلم يتأثر أي منهم معنويا بالأصناف أو بالتفاعل بين الأصناف ومعـــدلات التسميد الفوسفاتي،وان كانت هناك فروق في محصول البذور بين الأصناف المستخدمة في الدراسة في عامي الدراسة. كذلك أدي استخدام ٣١,٠ كجم للفدان من فو٢أ٥ آلي زيادة قدرها ٣٢% في محصول البذور في ٢٠٠٢، ١٨% في ٢٠٠٣ مقارنة باســـتخدام معدل ١٥,٥ كجم فو٢أ٥، بينما كانت الزيادة ١١% فقط في ٢٠٠٢، و ٤% في ٢٠٠٣ نتيجة زيادة المعدل آلي ٤٦,٥ كجم فو٢أ٥ .