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In the name of Allah

RELATIONSHIPS AMONG THE SEED YIELD FROM SMALL AND LARGE PLOTS IN COMMON BEANS[1]

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ABSTRACT

A uniformity trial was conducted on common beans (*Phaseolus vulgaris* L.) at the Bajgah Agricultural Experiment Station of the College of Agriculture, Shiraz, Iran, in 1982. A field was solidly planted with a Red Kidney bean cultivar and at harvest, the rows were divided into sections 1-m long and the seed yield of each section was determined separately. The adjacent 1-m units were combined into plots of various sizes and their yields were converted into kg/ha. No significant differences were found among the yields of small (1-m long) and large plots, thus making the use of small plots in bean experiments feasible. After calculating eight different equations, it was found that the relationship of best fit between the yield of small and large plots was quadratic in nature.

To further evaluate the results of the above experiment, data from two more experiments conducted at the Bajgah and Kooshkak Agricultural Experiment Stations were used. In both Experiments, a large number of cultivars belonging

تحقیقات کشاورزی ایران
جلد دوم شماره دوم

بنام خدا

رابطه بین عملکرد لوبیا از کرتهای کوچک وبزرگ

عبداله بصیری، منوچهر خردنام و محمدرضا مصطفوی
بترتیب استاد، استادیار و مربی بخش زراعت دانشکده کشاورزی دانشگاه شیراز

خلاصه

یک آزمایش یکنواختی در ایستگاه تحقیقاتی باجگاه دردانشکده کشاورزی دانشگاه شیراز در سال ۱۳۶۰ انجام گردید. یک رقم لوبیا قرمز در مزرعه کشت و هنگام برداشت، خطوط به قسمتهای یک متری تقسیم و بذر هر قسمت بطور جداگانه توزین شد. بمنظور ایجاد کرتهائی با اندازه‌های مختلف، واحدهای یکمتری مجاور با هم ترکیب و عملکرد حاصله به کیلوگرم در هکتار تبدیل گردید. تفاوت آماری معنی داری بین میزان محصول کرتهای کوچک وبزرگ مشاهده نگردید که این موضوع استفاده از کرتهای کوچک را در آزمایشات لوبیا توجیه مینماید. پس از محاسبه هشت معادله مختلف، معلوم شد که مناسب ترین رابطه بین عملکرد کرتهای کوچک و بزرگ از نوع درجه دو میباشد.

جهت اطمینان به نتایج آزمایش فوق، دو آزمایش دیگر در ایستگاههای تحقیقاتی باجگاه و کوشکک انجام گردید. در هر دو آزمایش از تعداد زیادی ارقام که در گروههای مختلف تجارتی لوبیا قرار داشتند استفاده گردید و اختلاف معنی داری بین میزان محصول از کرتهای یک متری و چهار متری مشاهده نشد که این موضوع نتیجه آزمایش قبلی را تائید مینماید. در این دو آزمایش نیز بنظر میرسد مناسب ترین رابطه، همان نوع درجه دو باشد.

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to different common bean commercial groups were used and the differences between the yields from 1-m and 4-m rows were found to be nonsignificant. This result supported that of the uniformity trial. Again, the best fit seemed to be quadratic.

INTRODUCTION

There avails a vast amount of information regarding plot size and shape and number of replications for field experiments for many crop species. These are important considerations which the experimenter should decide upon before conducting a field experiment on a given crop species (6). Among the research workers, breeders are more involved with these considerations, since they often must estimate the yielding potential of a large number of lines, and use of small plots saves them considerable time and labor (11).

Optimum plot size depends on the crop species, variability among cultivars or treatments, extent of soil heterogeneity, accuracy desired, and cost of land and experimental operations (3, 5, 17).

In cases where economy in research has been an important consideration, most investigators have used quadrats or rod rows instead of large plots. Several reports indicate that data obtained from quadrat sampling or the use of rod rows agree quite well with those of field plots (7, 10, 16).

Estimates of optimum plot size and replication number have generally been carried out by either using the Smith's regression coefficient or the coefficient of variability (C.V.). Smith (9) used a linear relationship between the logarithm of the variance among plots of a given size and the logarithm of plot size. He further incorporated the cost function in his estimates of optimum plot size. Results based on this method and on the use of the C.V. have been shown to agree quite well (6, 12, 15).

Common beans (*Phaseolus vulgaris* L.) are among the crops which require much labor for weeding and need copious amounts of irrigation water. Both are limiting factors in many experiment stations situated in southern Iran. Thus, ways need to be found to decrease the plot and field size in bean experiments. There is not enough information on the optimum plot size in this crop. Such information would be of great value statistically as well as economically. To such ends, this investigation was undertaken.

MATERIALS AND METHODS

Three separate experiments were carried out in the field at the Kooshkak and Bajgah Agricultural Experiment Stations of the College of Agriculture.

Experiment I

On May 22, 1982, 5-m long rows were planted with FAO 2006, a Red Kidney bean cultivar, at a rate of 75 kg/ha at the Bajgah Agricultural Experiment Station of the College of Agriculture, Shiraz University, 15 km north of Shiraz, Iran. There were 108 rows spaced 60 cm apart in a field measuring 10.8 x 30.0 m. The field was fertilized with 100 kg/ha of diammonium phosphate prior to planting. Common cultural practices were carried out during the growing season. At harvest, 50 cm from each end of the row were excluded to prevent border effect and the row was then divided into 1-m long portions. Each portion was harvested and threshed separately. The adjacent 1-m units were combined into plots of various sizes and their yields were converted into kg/ha.

Reasonable comparisons were made between various plot sizes for the mean yield. The differences between the average yields were tested for significance by t-test (14). The relationships between the yields from different plot sizes were then calculated using linear, logarithmic, parabolic, inverse linear, exponential, power, and quadratic curves, and for the equation of best fit the correlation coefficient was determined.

Experiment II

A field at the Kooshkak Agricultural Experiment Station, 75 km northwest of Shiraz, was divided into three sections. Each section was alloted to a variety trial carried out in four replications of a randomized complete block design. Ten bean cultivars were used in each section. Section 1 was planted with beans belonging to the Pinto commercial group, section 2 with Red Mexican and Red Kidney, and section 3 with Great Northern and Navy. The experimental field received 100 kg of diammonium phosphate prior to planting. Each plot was a 5-m long row, spaced 75 cm aprat and the seeding rate was 80 kg/ha.

Planting was done on June 1, 1981 and standard cultural practices were used throughout the growing season. At harvest, the first 50-cm sections from each end of the row were disregarded. Pods from 1-m length of one end of the row and those from the rest of the row were harvested separately and seeds from each were weighed and converted to kg/ha.

Data from the 1-m and 4-m long rows were correlated using statistical approaches similar to those used in Experiment I.

Experiment III

This experiment was conducted at the Bajgah Agricultural Experiment Station. Five different bean commercial groups (Pinto, Red Kidney, Red Mexican, Great Northern, and Navy) each containing five cultivars were used in this experiment. The design of the experiment was a split-plot in four replications with commercial groups forming the main treatments. Each plot consisted of three 5-m long rows, spaced 60 cm apart. Planting was done on May 22, 1982 at a rate of 80 kg/ha and prior to planting the field was fertilized with 100 kg/ha of diammonium phosphate.

At harvest, 50 cm from each end of the row were disregarded and only the middle row was considered. The division of the row into 1-m and 4-m long sections and the statistical handling of the yield data were the same as those described for Experiment I.

RESULTS

Experiment I

The mean yields per hectare from plots of different sizes were not significantly different from each other as determined by the t-test (Table 1). The greatest difference, although not significant, was found between the yields of 1-m and three 4-m rows; whereas, 4-m row yields were extremely close to those from the three 4-m rows. The coefficients of variability (C.V.) were in some cases quite large; however, larger plots had smaller C.V.'s.

After calculating the equations of eight different curves for the data, it was noted that quadratic curves provided the best fit for the relationships between the yields of smaller and larger plots (Table 2). The equation of best fit was selected on the basis of the multiple correlation coefficients (R); i.e., the greater the R value, the better the fit. All the R values reported in Table 2 were highly significant. The equations of next best fit were either the linear or the power curves; while, in most cases, inverse linear equations provided the poorest fit.

Experiment II

Beans planted at the Kooshkak produced relatively low yields. However, the differences in the yields from the 1-m and 4-m rows were not statistically significant (Table 3).

At this location, the values of the correlation coefficients were rather similar in magnitude for the power and quadratic curves; however, their magnitude for the power curve were slightly larger for all the three sections of the experiment. It should be noted that R values were highly significant for both the power and the quadratic

Table 1. Mean yields of the smaller (X) and the ecompassing larger plots (Y) and their corresponding coefficients of variability (C.V.) in Experiment I (Bajgah Agricultural Experiment Station, 1982).

Treat-ment No.	Comparison (X vs. Y)	Plot size (m^2)		Mean yield (kg/ha)			C.V. (%)	
		X	Y	X	Y	Differ-ence	X	Y
1	1-m rows vs. 4-m rows	0.6	2.4	2485	2417	ns	29.35	22.72
2	1-m rows vs. three 4-m rows	0.6	7.2	2181	2404	ns	27.46	19.28
3	1-m rows vs. five 4-m rows	0.6	12.0	2510	2329	ns	32.06	19.47
4	2-m rows vs. 4-m rows	1.2	2.4	2379	2417	ns	26.49	22.72
5	2-m rows vs. three 4-m rows	1.2	7.2	2259	2404	ns	25.99	19.28
6	2-m rows vs. five 4-m rows	1.2	12.0	2418	2329	ns	28.15	19.47
7	4-m rows vs. three 4-m rows	2.4	7.2	2359	2404	ns	22.12	19.28
8	4-m rows vs. five 4-m rows	2.4	12.0	2483	2329	ns	22.66	19.47
9	Two 4-m rows vs. four 4-m rows	4.8	9.6	2313	2334	ns	17.53	17.61
10	Three 4-m rows vs. five 4-m rows	7.2	12.0	2436	2329	ns	21.03	19.47

ns Not significant.

Table 2. Equations of best fit and multiple correlation coefficients (R) for the relationships between yields from various plot sizes in Experiment I (Bajgah Agricultural Experiment Station, 1982).

Treatment No.[†]	No. of observational pairs	Equation of best fit[§]	R
1	96	$Y= 616.3+0.9386X-0.000790X^2$	0.716**
2	30	$Y=1197.4+0.4636X+0.000038X^2$	0.817**
3	18	$Y= 856.6+0.9194X-0.000121X^2$	0.610**
4	96	$Y= 492.8+0.8593X-0.000020X^2$	0.877**
5	30	$Y=1179.4+0.4496X+0.000038X^2$	0.744**
6	18	$Y=1645.3+0.0073X+0.000104X^2$	0.740**
7	30	$Y= 115.3+1.1752X-0.000088X^2$	0.852**
8	18	$Y=1831.9-0.0756X+0.000131X^2$	0.679**
9	24	$Y=1017.2+0.3612X+0.000870X^2$	0.764**
10	18	$Y=3123.7-1.4376X+0.000438X^2$	0.698**

[†] See Table 1.

[§] X=Yield of smaller plots; Y=Yield of larger plots.

** Significant at the 1% probability level.

Table 3. Mean yields of the 1-m (X) and 4-m rows (Y), equations of best fit and next best fit, and multiple correlation coefficients (R) in Experiment II (Kooshkak Agricultural Experiment Station, 1981).

Field section	Commercial group cultivars	Mean yield (kg/ha)			Best fit		Next best fit	
		X	Y	difference	Equation	R	Equation	R
1	Pinto	1335	1181	ns	$Y=34.90X^{0.4892}$	0.698^{**}	$Y=437.8+0.6894X-0.000089X^2$	0.686^{**}
2	Red Mexican & Red Kidney	1447	1394	ns	$Y=9.99X^{0.6788}$	0.898^{**}	$Y=236.6+0.8858X-0.000049X^2$	0.862^{**}
3	Great Northern & Navy	1391	1321	ns	$Y=37.41X^{0.4938}$	0.817^{**}	$Y=559.6+0.5861X-0.000042X^2$	0.706^{**}

ns,** Not significant and significant at the 1% probability level, respectively.

curves (Table 3).

Experiment III

The results of this experiment were similar to those of previous experiments as far as the differences between the yields of smaller and larger plots were concerned (Table 4). However, contrary to Experiment II, the yields of the cultivars belonging to different commercial groups were much greater in 1982 at the Bajgah and the equations of best fit were quadratic (Table 4). Again like Experiment I, the equations of next best fit were either power or linear and the inverse linear relationships exhibited the poorest fit.

DISCUSSION

The results of the uniformity trial suggest strong relationships between the yields from plots of different sizes. However, since the main objective of this study was to determine associations between the yields from very small plots and larger plots, treatments 1, 2, and 3 seem to be of greater importance in this respect (Table 1).

The usual procedure for harvesting beans from experimental plots is cutting of the plants from the central rows (if the plot consists of more than a single row), after discarding the borders, and piling them to dry. The plants are then beaten by a wooden stick and the seeds are collected on canvas or the dried plants are directly fed into a plot thresher. Debris and dried leaves are then removed and clean seeds are weighed to obtain the plot yield. Seed loss which decreases the accuracy of yield estimates is a common problem with this method and untimely rains and fungal diseases may damage the pods appreciably. If smaller plots could provide a good estimate of the yield of larger plots, such difficulties could be minimized, since harvesting of a 1-m long plot, for example,

Table 4. Mean yields of the 1-m (X) and 4-m rows (Y) and equations of best fit and multiple correlation coefficients (R) in Experiment III (Bajgah Agricultural Experiment Station, 1982).

Commercial group cultivars	Mean yield (kg/ha)			Equation of best fit	R
	X	Y	Difference		
Pinto	3636	3465	ns	$Y=1016+0.8392X-0.000044X^2$	0.733**
Red Mexican	3605	3225	ns	$Y=153+1.2453X-0.000078X^2$	0.766**
Red Kidney	3477	3492	ns	$Y=3084-0.1618X+0.000076X^2$	0.745**
Navy	3593	3751	ns	$Y=2015+2.1356X-0.000137X^2$	0.940**
Great Northern	3848	3402	ns	$Y=3909-1.1156X+0.000240X^2$	0.947**
All cultivars	3632	3467	ns	$Y=1867+0.1875X+0.000065X^2$	0.782**

ns,** Not significant and significant at the 1% probability level, respectively.

could be achieved by hand picking of pods over a short period of time. In addition, all pods can be carefully picked with a minimum amount of labor and land usage, no seed loss occurs, fungal attacks are prevented, great savings are made in the use of irrigation water, fertilizers, and seed inoculants, and errors due to soil heterogeneity are minimized. These advantages are especially of great concern in plant breeding programs as well as in research involving a large number of plots. Reports showing the economical advantage of smaller over larger plots are numerous in the literature (1, 8, 11, 13).

The only drawback from using small plots is lower accuracy as is depicted from the C.V. values. The smaller the C.V., the more precise would be the estimates of effects and the more information could be obtained with the least cost (4). Since the C.V. is a function of the variance of the error term in the experiment, it is evident that a high C.V. value is indicative of a large error variance. A large error term may mask the actual differences existing among the effects of different treatments. The loss of accuracy from using very small plots can to a great extent be compensated for by increasing the number of replications in the experimental field since the size of the field will be greatly reduced by using short rows.

Although some authors consider values of C.V. greater than 15% (12) or at most 25% (2) to make the validity of the experiment doubtful, in practice, C.V. ranges between 5 and 50% in most biological experiments (4). Usually, the C.V.'s of field experiments are larger than those of greenhouse or laboratory experiments.

Since it is a common practice in bean experiments to get an estimate of the yield from a 4-m row, attention was concentrated in these experiments on the relationships between the yields of 1-m and 4-m rows. Data from the experiment conducted at Bajgah in 1982 supported the results of the uniformity trial closely. However, at Kooshkak, power curves provided slightly better relationships than the quadratic curves. It should be mentioned that at this location, weeds caused some damage to the crop. Whether the discrepancy observed is due to this factor or the differences in climatic conditions of the two locations needs further study.

The non-significant differences among the yields of different plots in these experiments (Tables 1, 3, and 4) suggest that regardless of plot size, the yield per hectare basis is statistically an almost constant value. Thus, the use of 1-m long rows would be economically justified. If one is also interested to study the relationship between the yields of small vs. large plots, a quadratic equation seems to be the best possible solution.

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