ROW WIDTHS AND PLANTING RATES OF SOYBEANS IN THE EASTERN FREE STATE

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(Met opsomming in Afrikaans)

Abstract

The relationships between potential yield and actual yield with various plant populations were investigated.

A reduction in the size of yield increments was apparent where narrow (46 cm) rows were used under conditions of high (circa 2 000 kg/ha) production potential. This was ascribed to the limiting effect of a too dense canopy on bean production. Where wide (92 cm) rows were used, more lateral irradiation was possible during seedset, resulting in higher yields than with narrow rows.

Narrow rows exploited the production potential of less favourable conditions, ie where vegetative growth was limited because of insufficient rainfall, to better advantage than wide rows, but under conditions of very low (600–700 kg/ha) potential, wide rows made better use of available moisture than did narrow rows – a reaction similar to that of maize under conditions of low rainfall in the Western Transvaal.

Plant populations between the (theoretical) limits of 213 000 to 869 000 plants per hectare appeared to have little or no effect on yield under conditions of high production potential. However, as production potential decreased, it became evident that reduced plant populations should be used and optimum plant population levels for various production potentials were established.

Intra-row spacings between 2,5 and 7,4 cm appear to have little or no effect on yield and a general between-plant spacing of 5 cm is recommended.

A model was constructed showing the relationship between row widths, plant population and potential yeild.

Introduction

The moisture supply, as determined by soil and rainfall characteristics, and its relationship with the moisture requirements of a crop, are the most important yield determinants in the Eastern Free State. No information is available concerning the moisture uptake of soybeans planted at different spacings in this area. Under conditions of low rainfall, du Plooy & le Roux (1968) showed that maize planted in wide (213 cm) rows made better use of available moisture, for grain production, than in rows half this width. There is no reason to believe that soybeans will not behave in a similar fashion although the same row widths need not necessarily apply. On the other hand experiments in five of the northern states of the USA showed that soybeans grown in 50 to 70 cm rows outyielded those grown in 80 to 100 cm rows by an average of 15 per cent. Rows 15 to 20 cm apart outyielded the 80 to 100 cm rows by only 7 per cent (Weber 1962), indicating a reduction of yield increments caused by too narrow rows.

According to Johnson, Cartter & Hartwig (1959), 40 to 70 cm rows showed a yield advantage over 80 to 110 cm rows, but only under certain conditions: full-season cultivars, planted early, gave practically the same yields whether planted in narrow or wide rows. In late plantings narrow rows outyielded wide rows. Hartwig (1957) came to the conclusion that the effect of row width on yield is determined by factors such as the length of the growing season, growth habit of cultivars and soil fertility. From a study of relevant literature, Caviness (1966) deduced that narrow rows gave higher yields than wide rows only under conditions where growth was limited by some or other factor.

Wiggins (1939) showed that bean yields of fixed plant populations increased as equidistance between plants was approached. Plant populations above six per square foot (about 643 000 per hectare) did not lead to an increase in yield.

In an article on the 'Management of Soybeans' Cartter & Hartwig (1963) quote a number of publications which indicate that intrarow spacings of 2,5 to 10 cm have little or no effect on yields, and that even moderate skips in one row of otherwise complete stands have little influence on total yield, eg "a 2-foot gap in a 16-foot row resulted in a very small and statistically non-significant yield reduction. A 4-foot gap resulted in a barely significant reduction and with a 6-foot gap 95 per cent of the check yield was produced." These findings were born out by yields obtained in practice – in the 1967 yield competitions in the USA for instance, intrarow spacings varying between 2,3 and 7,4 cm, all gave record yields and there seemed to be no relationship between yield and intrarowspacing, within these limits (Soybean Digest 1967).

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If moisture is not limiting, then the total leaf area available for photosynthesis is the main yield determinant. Shibles & Weber (1965, 1966) showed that soybeans could utilise high intensity radiation only about 67 per cent as effeciently as maize, measured in terms of dry matter production. The same authors came to the conclusion that soybean yields were determined mainly by the amount of light intercepted by the leaves: "Other environmental effects being equal, it is concluded that plant arrangement influences the efficiency of solar energy utilisation only within the context of the quantity of available energy intercepted. The most efficient arrangement of the plants, then, is that arrangement which presents the greatest total canopy surface during the growth cycle." That this statement must be qualified is indicated by Weber, Shibles & Byth (1965) who showed that bean production was not necessarily correlated with vegetative growth as the latter is mainly a function of light energy utilisation before seedset. One of the reasons for the correlation breakdown is given by the work of Van Schaik & Probst (1958) who reported that a sparse canopy led to more light penetration and less flower and pod abortion than a more dense one. In a review of literature Weber (1968) came to the following conclusion: "... cultural practices can be altered to take greater advantage of the environment, eg better plant distribution, thus giving more light interception and a higher yield..." He points out that if plants are shaded during the reproductive stage, a greater percentage of pods will abort than if they are not shaded. Continuous cloudy or misty weather which could reduce irradiation to the extent that yields are affected, seldom occur in the Eastern Free State. However, under favourable soil and climatic conditions, closely spaced soybeans may grow so luxuriantly during the vegetative stage that a dense canopy is formed by the time flowering and seedset starts. Thus light penetration to the lower parts of the plant may be limited. The extent of such limitation is indicated by Sakamoto & Shaw (1967) who found that most light is intercepted within the outer 15 to 30 cm of the canopy, as well as by Weber (1968) who reported that in a fully developed canopy, 90 per cent of the light energy was intercepted by 40 to 50 per cent of the leaves: "Leaves which do not photosynthesise efficiently are not necessarily parasitic, but represent, at the least, an inefficient use of water, plant nutrients and photosynthate."

With equal plant populations equidistantly planted soybeans will form a complete canopy in a shorter time than those planted in rows. The wider the rows, the more lateral irradiation is possible. During the reproductive stage, under conditions of luxuriant growth, wide rows will therefore make more effective use of available light energy than will narrow rows. As long as the rows are not so far apart than the effectiveness of water and nutrient uptake is greatly affected higher yields can then be expected from wide than from narrow rows.

Materials and methods

During the period 1966–1970 soybeans were grown in 13 factorial (3 x 3) experiments in the Eastern Free State at the localities specified in Table 1. Three row widths (92, 61 and 46 cm) were combined with three intrarow spacings (2,5; 3,8 and 5,1 cm) in all possible combinations and each experiment consisted of four replications. Fertilizer applications varied but were adequate in all cases so that in no case were differential responses expected as a result of nutrient deficiencies. All seed was inoculated with fresh soybean rhizobia. The cultivar Welkom was used in 12 of the 13 trials. The other trial (Trial 6) was planted to the cultivar Hill which is earlier in maturity than Welkom. The mean yield of each experiment was considered to reflect the potential yield for that particular experiment and used as a criterion to measure spacing reactions. The experimental sites, the numbers allocated to the experiments in order of yield, and planting and harvesting dates are given in Table 1.

TABLE 1 Planting and harvesting dates of soybean espacement trials

Place	Expt No*	Planting date	Harvesting date
Bethlehem	1	22.11.1966	15.5.1967
Bethlehem	2	1.12.1966	3.6.1967
Bethlehem	10	29.11.1967	–.5.1968
Bethlehem	9	25.10.1968	29.4.1968
Bethlehem	11	24.11.1969	18.5.1970
Bethlehem (Welkom)	12	6.11.1970	28.5.1971
Bethlehem(Hill)	6	6.11.1970	17.5.1971
Memel	4	26.10.1966	26.4.1967
Memel	8	6.11.1967	–.5.1968
Reitz	5	23.11.1966	9.5.1967
Senekal	3	18.11.1966	8.5.1967
Vrede	7	2.12.1966	17.5.1967
Heilbron	13	21.11.1967	6.5.1968

*Assigned according to yield rating

Results

Row widths

The mean yields obtained from the various interrow spacings are given in Table 2. Significant differences between spacings are found in five of the 13 trials. In localities 2 to 5 the narrower row widths tend to deliver a greater yield than the 92 cm. Only at locality 2 can the 46 cm yield be considered genuinely lower than the 61 cm yield.

In the case of locality 6, planted to the cultivar Hill, the apparent tendency is for a linear decrease in yield with increase in row width. However the differences are not significant. Similar apparent tendencies are evident at other localities. Hill was planted at the same locality as no 12 and at the same date. It produced almost double the yield

TABLE 2 Soybean yields at different interrow spacings (kg/ha)

Spacing	Experiment number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
46 cm	2 127	1 856	1 943	1 765	1 697	1 318	1 122	1 076	1 024	1 043	674	678	619
61 cm	2 256	2 087	1 832	1 735	1 526	1 180	1 153	1 153	1 096	971	742	687	588
92 cm	2 555	1 927	1 510	1 560	1 429	1 079	1 140	1 061	1 109	1 087	797	616	641
Mean	2 251	1 956	1 762	1 687	1 551	1 192	1 134	1 097	1 076	1 034	738	657	616
LSD	NS	178	212	143	165	NS	NS	NS	NS	NS	84	NS	NS
VR	1,45	3,72*	9,59*	5,47*	5,69*	2,06*	1	1,44	1	1	4,53*	1	1
CV	15,3%	10,8%	14,3%	10,1%	12,0%	21,0%	4,0%	12,8%	8,7%	16,3%	13,5%	36,6%	27,3%

F reqd. (P =0,05) 3,40

yield of no 12. Thus the early cultivar responded on a different scale to that of Welkom, but the response to row width did not deviate radically from that of Welkom. For purposes of the present analysis the difference in genotype may therefore be considered unimportant.

Row width	F Quadratic regression	F Linear regression		
46 cm	4,41	30,83	$Y = -338{,}4 + 1590{,}0X - 2137X^2$	(a)
61 cm	< 1	43,77	$Y = -50{,}5 + 1062{,}7X - 6{,}4X^2$	(b)
92 cm	7,25	< 1	$Y = 545{,}5 + 47{,}2X + 348{,}8X^2$	(c)
F reqd	(p =0,05) 4,96			
	(p =0,01) 10,04			

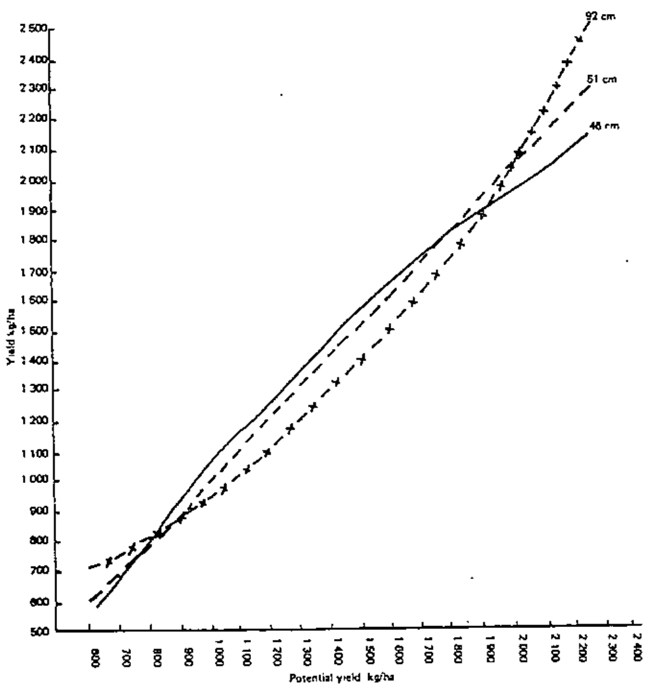

FIG 1 Soybean yields at different interrow spacings (kg/ha)

It appears that relatively little information is obtained regarding the effect of row width on yield when individual experiments are considered. However, when a particular row width is compared to the locality mean over all experiments, some associations emerge which appear to be more meaningful. The linear and quadratic regressions between individual row widths and the trial mean, were obtained, and are given in Figure 1. They show that a large but non-significant negative quadratic effect occurred with the narrow (46 cm) row width, while the wide (92 cm) spacing shows a significant positive quadratic effect. The lines intersect at potential yields of approximately 850 and 1 930 kg/ha. Below 850 and over 1 930 kg/ha the 92 cm row width gave the highest yield while between these potentials the 46 cm row width evidently exploited the potential to better advantage. It is evident that the interrow spacings progress from a negative quadratic effect in the case of the 46 cm row width to a linear effect at 61 cm to a positive quadratic effect at 92 cm row widths. The fitted line for the intermediate (61 cm) row width intersects the fitted lines for narrow and wide rows very nearly at the points where the latter cross, namely at about the 794 and 1 900 kg/ha yield levels. In terms of yield this means that there was a reduction in the size of yield increments with narrow rows and an increase with wide rows, concomitant with an increase in production potential.

Intra-row spacing

Linear and quadratic regression coefficients were also calculated for the individual intra-row spacings with the trial means over all trials. Fitted regression lines were similar to those obtained in the case of row widths in that they progressed from negative to linear to positive effects. This is illustrated by the regression equations which are as follows:

2,5 cm : $Y = -240{,}6 + 1\,407{,}1\,X - 158{,}5\,X^2$

3,8 cm : $Y = -\ 90{,}3 + 1\,186{,}9\,X - 66{,}5\,X^2$

5,1 cm : $Y = -331{,}7 + 405{,}3\,X + 225{,}2\,X^2$

TABLE 3 Soybean yields at different inter- and intrarow spacings (kg/ha)

Intra spacing	Theoretical plant population	Experiment number													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
	x 1 000 ha														
46 cm															
2,5 cm	869	1 715	1 740	2 040	1 760	1 578	1 200	1 201	848	984	954	717	693	648	1 237
3,8 cm	572	2 304	1 767	1 866	1 806	1 774	1 509	1 136	1 203	1 041	1 142	641	739	685	1 355
5,1 cm	426	2 361	2 063	1 922	1 730	1 739	1 245	1 028	1 187	1 047	1 033	665	602	525	1 319
61 cm															
2,5 cm	655	2 300	2 128	1 824	1 752	1 498	1 181	1 217	1 171	1 013	958	669	676	582	1 305
3,8 cm	431	2 137	1 968	2 008	1 832	1 554	1 103	1 187	1 075	1 131	901	746	727	573	1 305
5,1 cm	321	2 354	2 164	1 664	1 623	1 527	1 257	1 024	1 218	1 145	1 053	794	632	613	1 313
92 cm															
2,5 cm	434	2 246	1 737	1 788	1 666	1 546	1 181	1 260	983	1 144	1 105	770	486	633	1 273
3,8 cm	286	2 306	2 010	1 708	1 536	1 519	959	1 325	1 107	1 110	1 038	830	535	645	1 279
5,1 cm	213	2 555	2 036	1 033	1 478	1 222	1 097	834	1 094	1 072	1 118	790	827	648	1 216
Mean		2 251	1 956	1 762	1 687	1 551	1 192	1 134	1 097	1 076	1 034	738	657	616	1 289
LDS		NS	NS	367	NS	NS	NS	NS	119	NS	NS	NS	NS	NS	
VR		1,34	1,36	3,12*	1	1,69	3,01	2,22	2,78*	1,23	1	1,18	1,30	1	
CV		15,3%	4,8%	6,4%	10,1%	5,6%	21,0%	4,0%	12,8%	8,7%	16,3%	13,5%	36,6%	27,3%	

F reqd. (P =0,05) 2,78

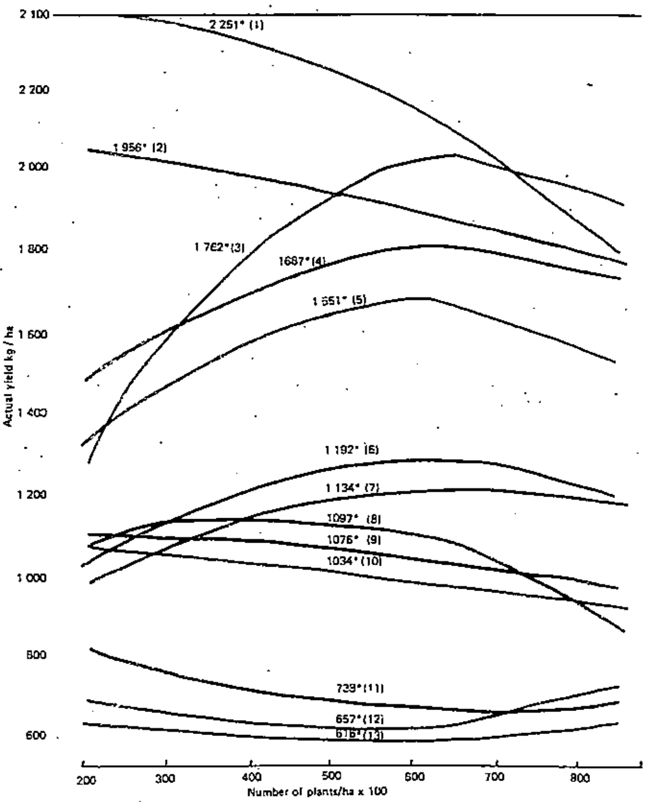

FIG 2 Effect of plant population on yield under conditions of different production potentials (experiment numbers in parenthesis)

TABLE 4 Variance ratios and regression equations of plant population x production potential regressions

Exp no	Yield potential kg/ha	F Quadr regr	R Lin regr	Regression equation
1	2 251	1,13	1	$2\,367 + 451X - 1\,271X^2$
2	1 956	1	1	$2\,125 - 319X - 76X^2$
3	1 762	4,16	6,50*	$462 + 4\,621X - 3\,374X^2$
4	1 687	11,11*	16,30*	$1\,083 + 2\,196X - 165X^2$
5	1 551	5,30	6,56*	$825 + 2\,810X - 2\,303X^2$
6	1 192	1,57	2,09	$693 + 1\,882X - 1\,488X^2$
7	1 134	1	1,20	$720 + 1\,491X - 1\,108X^2$
8	1 079	3,17	2,06	$867 + 1\,295X - 1\,464X^2$
9	1 076	1	1	$1\,088 + 169X - 356X^2$
10	1 034	1	1	$1\,111 - 155X - 17X^2$
11	738	3,24	4,99	$1\,015 - 991X + 738X^2$
12	657	1	1	$834 - 813X + 796x^2$
13	616	1,05	1	$719 - 465X + 447X^2$

F (P = 0,05) 5,99

(P = 0,01) 13,74

No significant quadratic effects were obtained for intra-row spacings as shown by the following F values:

		F quadratic regression	*F linear regression*
2,5 cm		3,60	35,84
3,8 cm		2,12	86,86
5,1 cm		3,52	1,44
F required	(p=0,05)	4,96	
	(P=0,01)	10,04	

The significant linear responses to intra-row spacings can be satisfactorily explained by the related increases in plant populations (plant population and spacings are confounded with each other). Furthermore, a study of relevant literature showed that intra-row spacing have little or no effect on yield (ia Cartter & Hartwig 1963; Soybean Digest 1967). Therefore it was concluded that intra-row spacing did not play an important role in determining yields.

Plant populations

No counts of the actual populations in the experiments were made. However the data was analysed on the basis of the theoretical population numbers based on spacing; as the stands were good and easily observable differences in stand occurred, it was accepted that the actual populations were proportional to the calculated theoretical populations. The actual number of plants was probably less than the figures given in Table 3.

The yields obtained at the different spacings, representing various plant populations, are shown in Table 3. The regressions of yield on plant population under conditions of varying potential were calculated and the results are shown in Table 4 and Figure 2.

At high (2 251 kg/ha — experiment 1, and 1 956 kg/ha — experiment 2) production levels, there was an apparent decrease in yield concomitant with an increase in plant population (Figure 2). As the yield-population regression values for these two experiments were not significant (Table 4), this apparent decrease cannot be ascribed to increases in plant populations. Bearing in mind that narrow rows (which are confounded with high plant populations) have a limiting effect on yield under conditions of high production potential (Caviness 1966) it is considered that the apparent yield reduction shown by the two high potential experiments was caused by the reduction in row width and not necessarily by the increase in population size. Wide rows evidently exploited the favourable conditions pertaining at the sites of these experiments to greater advantage than narrow rows, while plant populations had no measurable effect.

In the case of experiments 3, 4 and 5, one significant and two nearly significant quadratic effects were obtained (Table 4). From Figure 2 it may be seen that this indicated an optimum plant population in the region of 572 000 to 655 000 plants per hectare. These plant populations were obtained with spacings of 46 x 3,8 and 61 x 2,5 cm, indicating that intermediate to narrow rows exploited the potential of these conditions to best advantage. Thus, at the intermediate production potential, population size places a limitation on the yield. Experiments 6 and 7 showed a similar tendency and although no significant regressions were obtained they are classed with experiments 3, 4 and 5. The yield potential for this whole group is considered to fall in the range 1 134 to 1 762 kg/ha for the 572 000 to 655 000 population range.

Experiments 8, 9 and 10 represent a lower production potential than the abovementioned and although no significant effects were obtained, the fitted lines in Figure 2 indicate an optimum plant population in the region of 321 000 to 434 000 per hectare.

The following spacings would give plant populations in this range:

61 x 5,1 cm — 321 000 plants/ha
46 x 5,1 cm — 426 000 plants/ha
61 x 3,8 cm — 431 000 plants/ha
92 x 2,5 cm — 434 000 plants/ha

From these data it appears that, at a low production potential (1 034 to 1 097 kg/ha), row width is of little importance, but the number of plants should be within the range 321 000 to 434 000/ha.

In experiment 2 there was a large, but not significant, linear effect, indicating yield reductions at populations greater than 213 000 per hectare. This population was obtained only with wide inter-row spacings. These low potential conditions were therefore optimally exploited by the combination of low plant populations with wide rows, a situation similar to that pertaining for maize in the low rainfall areas of the Western Transvaal as described by du Plooy & le Roux (1968).

Discussion

The interrelationships and interactions of various yield components were pertinently illustrated by this study. It is evident that row widths and plant populations should be adjusted according to the yield potential of the situation under which soybeans are to be grown.

Under conditions which favour luxuriant vegetative growth, irradiation is likely to become the limiting factor and row widths which present the greatest possible canopy surface to the light, should be chosen.

Under less favourable conditions vegetative growth is limited and spacings and populations which exploit whatever factor is limiting, to best advantage, should be chosen.

TABLE 5 *Plant populations and spacings where optimal productions was realised at various yield levels*

Potential Range kg/ha	Yield kg/ha Mean	Population x 1 000	Row width cm	Intra row cm
		(Fig 2)	(Fig 1)	(Calculated)
600– 850	725	213	92	5,0
	794 (Table 3)	321(Table 3)	61	5,0
850–1 100	975	430	46	5,0
1 100–1 800	1 450	655	46(30)	3,3(5,0)*
1 800–2 000	1 900 (Table 3)	321(Table 3)	61	5,0
2 000–2 250	2 125	213	92	5,0

*Taking into account the fact that higher plant populations were associated, in five out of the six cases, with 5 cm intra-row spacing and were made possible by decreases in row widths (ie a greater number of rows per unit area) it can be deduced that, in this case (655 000 plants per hectare in 46 cm rows), a narrower interrow spacing is to be recommended.
If the same intrarow spacing is applied as at the other row widths (ie 5 cm) then a 30 cm row width will accommodate the relevant number of plants. This row width (30 cm) was therefore used in order to draw up the model (Fig 3).

Thus, if soil moisture or fertility, or a short growing season, is the cause of limited growth, narrower rows will be able to make better use of the production potential. However, under extreme conditions of eg low soil moisture, it is advisable to revert to wide rows and low plant populations.

From the results of these experiments and from relevant literature, it appears that intra-row spacings between the limits of 2,5 to 7,4 cm, have little direct effect on yield. Narrow intra-row spacings (2,5 cm) improve the chances of obtaining a good stand under unfavourable germinating conditions, give a quicker ground cover and compete better with weeds than wide intra-row spacings. They are however inclined to lodge more easily and may double the cost of seed as compared to wider intrarow spacings. Based on the results of these experiments as well as on the data reviewed in the Introduction, an intra-row spacing of 5 cm between plants is recommended. Plant populations can be varied by varying row widths while keeping intra-row spacings constant at this figure.

These recommendations can be quantitatively illustrated by means of a model. The plant populations and row widths which gave rise to the most efficient exploitation of the various production potentials are shown in Table

(Intra-row spacing: 5 cm throughout)

F quadratic regression 37,76
F required (P =0,05) 34,12

$$Y = 265,79 - 34,32X + 1,23X^2$$

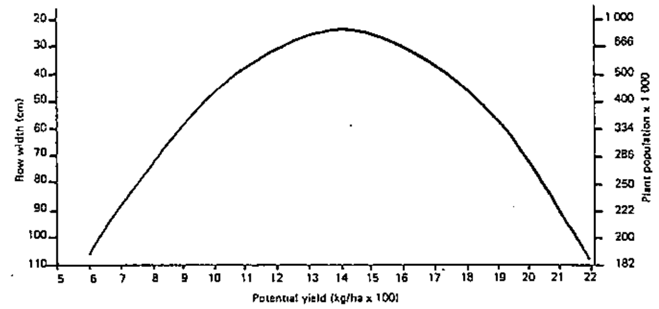

FIG 3 *Recommended row widths and plant populations for soybeans at different yield levels, in the Eastern Free State*

5. From these data the regression of row width on potential yield was calculated and this is shown in Figure 3. The concomitant plant populations (with an intra-row spacing of 5 cm between plants) were calculated and are also shown.

Potential application of the model

The aforementioned data (Figure 3) is of no value to a producer if he does not know or cannot determine the production potential of the land on which he intends planting soybeans.

Möhr & van Niekerk (1972) developed a method for determining potential maize yields by means of integrating various yield components. If a relationship between maize and soybean production can be found it should be possible to determine potential soybean yields by means of their method.

In the USA it is generally accepted that maize yields are two to three times that of soybeans, say a ratio of 2,5:1, under conditions where maize gives a yield of 5 000 kg/ha. In other words, where maize yields 5 000 kg/ha, a soybean yield of 2 000 kg/ha may be expected. Based on yield studies (van Niekerk 1966) ia in the Lydenburg district, van Niekerk (1971) stated that maize and soybean yields broke even at about 1 000 kg/ha. Below this yield soybeans outyield maize, while maize outyield soybeans at higher production levels. From these data the relationship between maize and soybean yields was calculated and is shown in Figure 4. If maize yields are calculated according to the method of Möhr & van Niekerk and the relation-

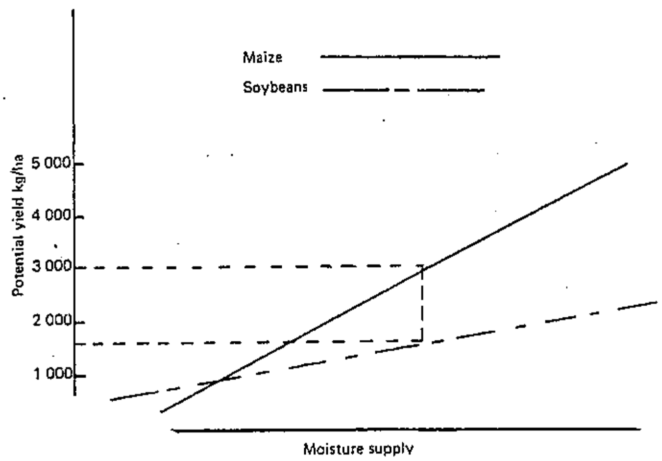

FIG 4 The relationship between the production potential of maize and soybeans

ship in Figure 4 is used, the corresponding soybean yield can be determined, eg as shown by the dotted line in Figure 4.

Opsomming

RYWYDTES EN PLANTESTAND VIR SOJABONE IN DIE OOSTELIKE VRYSTAAT

Die verband tussen potensiële opbrengs en werklike opbrengs by verskillende plantestande is ondersoek.

In die geval van nou rye (46 cm) by hoë produksiepotensiaal (ca 2 000 kg/ha) is 'n vermindering van opbrengsinrkemente gevind. Dit word toegeskryf aan die beperkkende effek van 'n te digte blaredak by bone. By wye rye (92 cm) was meer laterale straling tydens saadset moontlik met die gevolg dat hoër opbrengste verkry is.

Nou rye het die produksiepotensiaal onder minder gunstige toestande beter benut as wye rye, di waar vegetatiewe groei deur onvoldoende reënval beperk is. By baie lae produksiepotensiaal (600–700 kg/ha) het wye rye egter die beskikbare vog beter benut as nou rye – 'n reaksie soortgelyk aan dié van mielies onder lae reënvaltoestande in Wes-Transvaal.

Plantestande tussen die teoretiese grense 213 000 en 869 000 plante per hektaar het blykbaar min of geen effek op opbrengs onder hoë potensiaaltoestande gehad nie. Met afname in produksiepotensiaal moet laer plantestande egter gebruik word. Optimum peile vir plantestand vir verskillende produksiepotensiale is bepaal.

Wisseling van intra-ry spasiëring tussen 2,5 en 7,4 cm beïnvloed nie die opbrengs nie en daarom word 5 cm tussen plante in die algemeen aanbeveel.

'n Model waarin die verband tussen rywydtes, plantestand en potensiële opbrengs getoon word, is opgestel.

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