THE USE OF HEAT UNITS IN MAIZE PRODUCTION
PART II EXPERIMENTAL RESULTS

(Met opsomming in Afrikaans)

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Abstract

The maize hybrid SA4 was planted in a planting date experiment at the Agricultural Research Station of African Explosives and Chemical Industries Limited at Bapsfontein over a period of five years (1964/65-1968/69). The stages of 50 per cent pollen shedding and 50 per cent silking were determined each year and the lengths of the periods from planting to flowering (pollen shedding and silking) and from emergence to flowering were expressed in number of days and in heat units. It was found that no definite preference could be given to either of the methods, probably due to the fact that the experiment was carried out at one location only.

In order to establish the development of SA4 plants under conditions of widely varying temperatures, seed was sent to and planted at Oxford (England) and Arlington (Wisconsin, USA) in 1968 and 1969. The number of days and heat units recorded at these centres for the periods from planting to flowering was compared with those found at Bapsfontein.

The results showed that the length of these periods varied considerably less due to location when expressed in heat units than when expressed in number of days.

Introduction

The use of heat units as a means of expressing the length of the different growing stages of a maize plant has been accepted in the USA (Aldrich & Leng, 1966), and in Canada (Holmes & Robertson, 1959), in preference to systems based on number of days or maturity ratings.

In South Africa dry weather conditions occur frequently in midsummer. If this dry period coincides with the time of flowering of the maize plants, considerably harmful effects on the yield can be expected. By determining the heat requirements of the different hybrids from planting to flowering it would be possible to draw up a planting programme for these hybrids in such a way that flowering would not take place during the midsummer drought. The time is opportune in South Africa for the introduction of the heat unit system as many new hybrids, which are unknown quantities as far as their adaptability is concerned, are appearing on the market.

Methods, procedures and results

The South African hybrid SA4 was planted at the Agricultural Research Station of African Explosives and Chemical Industries Limited at Bapsfontein in a planting date experiment over a period of five seasons (1964/65-1968/69). A randomized block design with four replications was used. The amount of fertilizer, which was applied, gave 151 kg N, 61 kg P, and 79 kg K per hectare. The dates on which 50 per cent of the plants were shedding pollen and showing silks were determined for all four plantings. The number of days and heat units from planting to flowering and from emergence to flowering were then computed.

In order to assess the influence of different locations with widely varying weather conditions on the number of days and heat units for the period from planting to flowering, seed of SA4 was sent to Arlington, Wisconsin, USA and Oxford, England. The seed was planted at Research Stations in a randomized block with four replications. Flowering data and maximum and minimum temperatures were obtained. From these the number of days of heat units from planting to flowering were calculated.

(A) Date of planting experiment

Bapsfontein 1964/65 to 1968/69

The dates of planting, the condition of the seedbed as far as moisture is concerned at the time of planting and the number of days from planting to emergence for each of the five seasons are given in Table 1.

TABLE 1 Number of days between planting and emergence

Season	Planting dates	Condition of seedbed	Number of days from planting to emergence
1964-65	6.10	dry	19
	23.10	fair	10
	9.11	moist	7
	26.11	dry	18
1965-66	5.10	dry	21
	22.10	dry	19
	8.11	fair	11
	25.11	fair	10
1966-67	4.10	dry	22
	22.10	moist	10
	7.11	moist	9
	24.11	moist	7
1967-68	3.10	dry	19
	20.10	dry	15
	6.11	moist	7
	23.11	moist	7
1968-69	8.10	dry	30
	25.10	dry	27
	13.11	fair	12
	28.11	moist	7

In all five seasons the first planting took place in dry soil before the start of the spring rains. In the 1964/65 season the month of November was extremely dry (11,6 mm of rain for the month), which caused the delay in emergence of the plants in the fourth planting.

The 1965/66 and 1968/69 seasons were unfavourable as far as rainfall was concerned with a total of 146 mm and 195 mm of rain respectively for the months of October, November and December.

In 1966/67 and 1967/68 the rainfall was good. However, the spring rains started late in 1967, so that at the time of the second planting the soil was still dry.

For each planting, the dates of 50 per cent emergence, 50 per cent pollen shedding and 50 per cent silking were determined.

The number of heat units accumulated between planting and pollen shedding, between planting and silking, between emergence and pollen shedding, and between emergence and silking were calculated using the remainder index system:

$$\frac{\text{max temp (°C)} + \text{min temp (°C)}}{2} - 10°C \text{ for each day}$$

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Results

Tables 2 to 5 show the number of days between planting and pollen shedding, planting and silking, emergence and pollen shedding, and emergence and silking in that order for each of the five seasons.

TABLE 2 Number of days between planting and pollen shedding

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	93,3	81,5	77,0	83,5	83,8
1965-66	92,8	90,5	79,5	72,8	83,9
1966-67	88,3	76,5	75,0	68,5	77,1
1967-68	91,0	84,0	73,8	73,0	80,4
1968-69	104,0	89,8	74,0	69,3	84,3
Mean	93,9	84,5	75,9	73,4	

CV 1,66%
LSD to compare planting dates: 5% level 0,9
1% level 1,2
LSD to compare seasons: 5% level 1,0
1% level 1,3
LSD to compare planting dates x seasons 5% level 1,9
1% level 2,6

TABLE 3 Number of days between planting and silking

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	94,0	83,3	77,8	85,0	85,0
1965-66	114,3	99,0	85,3	77,8	94,1
1966-67	90,0	78,5	73,5	71,3	78,3
1967-68	92,3	85,0	76,5	74,0	81,9
1968-69	106,3	98,5	83,8	77,8	91,6
Mean	99,4	88,9	79,4	77,2	

CV 2,29%
LSD to compare planting dates: 5% level 1,3
1% level 1,7
LSD to compare seasons: 5% level 1,4
1% level 1,9
LSD to compare planting dates x seasons: 5% level 2,8
1% level 3,8

TABLE 4 Number of days between emergence and pollen shedding

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	74,8	71,8	70,0	65,0	70,4
1965-66	71,0	72,3	69,0	63,0	68,8
1966-67	66,3	67,0	66,3	61,8	65,3
1967-68	71,5	69,0	66,3	65,5	68,1
1968-69	73,5	62,8	62,0	62,5	65,2
Mean	71,4	68,6	66,7	63,6	

CV 2,21%
LSD to compare planting dates: 5% level 1,0
1% level 1,3
LSD to compare seasons: 5% level 1,1
1% level 1,4
LSD to compare planting dates x seasons: 5% level 2,1
1% level 2,8

TABLE 5 Number of days between emergence and silking

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	75,3	73,5	70,8	66,5	71,5
1965-66	92,5	80,8	74,8	68,0	79,0
1966-67	68,0	69,0	64,8	64,5	66,6
1967-68	72,8	70,0	69,0	66,5	69,6
1968-69	75,8	71,5	71,8	71,0	72,5
Mean	76,9	73,0	70,2	67,3	

CV 3,66%
LSD to compare planting dates: 5% level 1,7
1% level 2,2
LSD to compare seasons: 5% level 1,9
1% level 2,5
LSD to compare planting dates x seasons: 5% level 4,9
1% level 6,6

TABLE 6a Summary of significant differences in days due to planting dates

Period	Significant differences	Level of significance	
Planting to pollen shedding ...	T1> T2> T3> T4	5%	1%
Planting to silking ...	T1> T2> T3> T4	5%	1%
Emergence to pollen shedding ...	T1> T2> T3> T4	5%	1%
Emergence to silking	T1> T2> T3> T4	5%	1%

Table 6a gives a summary of the significant differences due to planting dates.

The four planting dates are indicated by T1, T2, T3 and T4.

TABLE 6b Summary of significant differences in days due to seasons

Period	Significant differences	Level of significance	
Planting to pollen shedding ...	S5 S2 S1> S4> S3	5%	1%
Planting to silking ...	S2> S5> S1> S4> S3	5%	1%
Emergence to pollen shedding ...	S1> S2 S4> S3 S5	5%	1%
Emergence to silking	S2> S5 S1> S4> S3	5%	—

Table 6b gives a summary of the significant differences in the number of days due to seasons.

The five seasons are indicated by S1, S2, S3, S4 and S5.

Significant differences in the number of days from planting to flowering and from emergence to flowering due to planting dates, to seasons and to the interaction planting dates x seasons were found.

Tables 7 to 10 show the heat units accumulated during the periods planting to pollen shedding, planting to silking, emergence to pollen shedding and emergence to silking.

TABLE 7 Heat units from planting to pollen shedding

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	758	685	680	777	725
1965-66	830	944	836	800	852
1966-67	786	721	707	691	726
1967-68	796	775	701	727	750
1968-69	979	878	738	782	844
Mean	830	800	732	755	

CV 2,06%
LSD to compare planting dates: 5% level 9
1% level 12
LSD to compare seasons: 5% level 10
1% level 14
LSD to compare planting dates x seasons: 5% level 21
1% level 28

TABLE 8 Heat units from planting to silking

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	764	702	687	787	735
1965-66	1 082	1 032	895	839	961
1966-67	802	740	691	719	738
1967-68	805	785	732	734	764
1968-69	1 009	982	851	859	925
Mean	892	848	771	788	

CV 3,30
LSD to compare planting dates: 5% level 17
1% level 23
LSD to compare seasons: 5% level 19
1% level 26
LSD to compare planting dates x seasons: 5% level 39
1% level 52

TABLE 9 Heat units from emergence to pollen shedding

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	619	623	601	625	617
1965-66	720	762	758	708	737
1966-67	629	634	648	613	631
1967-68	641	652	631	656	645
1968-69	718	676	672	718	696
Mean	665	669	662	664	

CV 2,11%
LSD to compare planting dates: 5% level 9
1% level 12
LSD to compare seasons: 5% level 10
1% level 13
LSD to compare planting dates x seasons: 5% level 20
1% level 27

TABLE 10 Heat units from emergence to silking

Season	Planting				
	1st	2nd	3rd	4th	Mean
1964-65	624	639	608	635	627
1965-66	922	850	817	747	834
1966-67	645	654	632	641	643
1967-68	650	663	665	663	660
1968-69	748	780	785	790	776
Mean	718	717	701	695	

CV 5,95%
LSD to compare planting dates: 5% level 27
1% level 36
LSD to compare seasons: 5% level 30
1% level 40
LSD to compare planting dates x seasons: 5% level 60
1% level 80

TABLE 11a Summary of significant differences in heat units due to planting dates

Period	Significant differences	Level of significance	
Planting to pollen shedding	T1> T2> T4> T3	5%	1%
Planting to silking ...	T1> T2> T4> T3	5%	1%
Emergence to pollen shedding ...	NS	—	—
Emergence to silking	NS	—	—

Table 11a gives a summary of the significant differences in heat units due to planting dates.

The four planting dates are indicated by T1, T2, T3 and T4

TABLE 11b Summary of significant differences in heat units due to seasons

Period	Significant differences	Level of significance	
Planting to pollen shedding	S2 S5> S4> S3 S5	5%	1%
Planting to silking	S2> S5> S4> S3 S1	5%	1%
Emergence to pollen shedding ...	S2> S5> S4> S3> S1	5%	1%
Emergence to silking	S2> S5> S4> S1 S2> S5> S3	5% 5%	— 1%

Table 11b gives a summary of the significant differences in heat units due to seasons.

The five seasons are indicated by S1, S2, S3, S4 and S5.

As in the case of the number of days, significant differences in the number of heat units accumulated between planting and flowering and between emergence and flowering due to planting dates, to seasons and to the interaction planting dates x seasons were found.

Discussion

The choice beween the use of day units or of heat units to express the length of the periods from planting and from emergence to flowering depends on the degree of variability of either unit due to planting date and to season. The unit showing the least variation should be used.

Planting dates

The five-year results summarized in Tables 6a and 11a show that for the period from planting to flowering (pollen shedding and silking) the number of days and of heat units varied to the same extent for the different dates of planting. Most of the variation was caused by the fact that the plants in the first and second plantings required considerably more days and heat units to reach the flowering stage than those in the third and fourth plantings. The reason for this result was that the emergence of the plants in the first two plantings was much slower due to the dry conditions of the seed bed earlier in the season. Averaged over the five seasons emergence in the first, second, third and fourth plantings took place after 22, 16, and 10 days respectively.

The number of heat units was a more reliable means of expressing the length of the period from emergence to flowering than the number of days, as no significant differences due to planting dates were found for the former, while the latter did show significant differences.

Seasons

For all periods (planting and emergence to flowering) the number of days showed less variation than the number of heat units (Tables 2, 3, 4, 5, 7, 8, 9 and 10), although

significant differences were found in both cases (Tables 6b and 11b).

However, in the seasons with good rainfall (1964/65, 1966/67 and 1967/68) the heat units varied less than the number of days.

The severe drought conditions experienced between planting and flowering in 1965/66 and 1968/69 delayed pollen shedding and especially silking. During these dry periods the mean daily temperatures were higher than in the corresponding periods in the seasons with good rainfall. Consequently the increase in the number of heat units, caused by the delay in flowering, was relatively higher than that in the number of days.

Planting dates x seasons

In general the results of the interactions were similar to those of the main effects.

The results of this experiment show that no definite preference could be given to either the number of days or the number of heat units as a means of expressing the length of the period from planting to flowering.

This experiment was carried out at the same location every year with a relatively limited range of weather conditions.

In order to establish the development of SA4 plants under widely different weather conditions, the following experiment was undertaken.

(B) Flowering of SA4 at different locations

Seed of SA4 was planted at Research Stations in Oxford (England) in 1969 and in Arlington (Wisconsin, USA) in 1968 and 1969.

Replicated data on dates of flowering were received from these centres.

The number of days and the number of heat units for the period from planting to flowering (pollen shedding and silking) at Oxford in 1969, at Arlington in 1968 and 1969 and at Bapsfontein in 1966/67 and 1967/68 were analysed statistically. The results are given in Table 12.

To calculate the number of heat units the remainder index system as amended by Gilmore & Rogers (1958) was used viz the temperatures below 10°C were taken as 10°C and those above 30°C as 30°C. The reason for this adjustment is that ineffective temperatures below 10°C occurred during the early season at Oxford and above 30°C in the middle of the season at Arlington.

Number of days : planting to pollen shedding
CV 0,83%
LSD to compare location means 5% 1,1
1% 1,5
Number of days : planting to silking
CV 0,98%
LSD to compare location means 5% 1,3
1% 1,9
Heat units : planting to pollen shedding
CV 0,68%
LSD to compare locations means 5% 7,8
1% 10,9
Heat units : planting to silking
CV 1,01%
LSD to compare location means 5% 12,1
1% 16,9

The significant differences are summarized in Table 13.

TABLE 13 *Significant differences in flowering of SA4 at different locations*

Period	Significant differences	Level of significance	CV %
	Number of days		
Planting to pollen shedding	L1 > L2 > L4 > L3 L5	%	0,83
Planting to silking	L1 > L2 > L4 L3 L5	1%	0,98
	Heat units		
Planting to pollen shedding	L2 > L3 > L1 L4 L5 L1 > L5	1%	0,68
Planting to silking	L2 > L3 > L1 L5 L4	1%	1,01

Discussion

Significant differences due to location were found between the number of days as well as between the number of heat units for both periods (planting to pollen shedding and planting to silking).

The greatest difference in number of days existed between Oxford (L1) on the one hand and Bapsfontein '67 (L5) and Arlington '68 (L2) on the other hand. This difference was 43 days to pollen shedding and 45 days to silking.

The number of heat units recorded to pollen shedding at Oxford (L1) was 14 higher than at Bapsfontein '67 (L5) and 65 lower than at Arlington '68 (L2).

The average number of heat units accumulated per day was 6,2 at Oxford, 9,6 at Bapsfontein and 9,0 at Arlington.

TABLE 12 *Flowering of SA4 at different locations*

Location		Date of planting	Number of days from planting to pollen shedding					Number of days from planting to silking				
			Replication				Mean	Replication				Mean
			1	2	3	4		1	2	3	4	
Oxford	L1	7.5.69	117	117	115	118	117	123	122	121	120	122
Arlington	L2	10.5.68	88	88	88	88	88	91	91	91	91	91
Arlington	L3	9.6.69	74	74	74	74	74	77	77	77	77	77
Bapsfontein	L4	22.10.66	76	77	77	76	77	77	88	79	78	79
Bapsfontein	L5	6.11.67	74	73	74	74	74	76	77	76	77	77
			Heat units									
Oxford	L1	7.5.69	731	731	720	735	729	763	758	752	746	755
Arlington	L2	10.5.68	794	794	794	794	794	832	832	832	832	832
Arlington	L3	9.6.69	749	749	749	749	749	781	781	781	781	781
Bapsfontein	L4	22.10.66	714	723	723	714	719	723	758	746	735	741
Bapsfontein	L5	6.11.67	718	706	718	718	715	739	748	739	748	744

Consequently the difference of 14 heat units between Oxford and Bapsfontein '67 meant 2,3 days at Oxford and 1,5 days at Bapsfontein, while the 65 heat unit difference between Oxford and Arlington was equivalent to 10 days at Oxford and seven days at Arlington.

Similar results were obtained with regard to silking.

These results show that the prediction of the time of flowering at the different locations could be done with more accuracy on the basis of heat units than on the basis of number of days.

The results obtained at Arlington in 1968 and 1969 differ considerably. The number of days and of heat units to pollen shedding were 14 and 15 respectively more in 1968 than in 1969.

There must have been a factor unknown to the author, which delayed flowering, as both number of days and heat units were effected. However, the number of days was also influenced by the fact that in 1968 the mean temperature was lower (9 heat units per day) than in 1969 (10 heat units per day).

Conclusion

Hybrids which have been developed in a certain area can be grown in other areas, which have widely different temperature regimes.

As the plants grow and develop more slowly when the temperature is low than when it is high, the use of the number of days as a means of expressing the length of developmental stages is unsatisfactory. Under normal rainfall conditions heat units are considerably more reliable.

Although extreme dry conditions will cause erroneous results it is felt that in the majority of cases heat units form a better basis for recommendations of the adaptability of hybrids than the number of days.

Opsomming

DIE GEBRUIK VAN WARMTE-EENHEDE IN MIELIEVERBOUING DEEL II Proef-resultate.

Die mieliebaster SA4 is in 'n plantdatumproef op die Landboukundige Navorsingsstasie van Afrikaanse Misstowwe en Chemiese Nywerhede by Bapsfontein oor 'n periode van vyf jaar (1964/65-1968/69) geplant. Die tydstip waarop 50 per sent van die plante stuifmeel gestort en baard vertoon het is elke jaar vasgestel en die lengte van die periode van plant tot blom (stort van stuifmeel en uitkom van die baard) en van opkoms tot blom is uitgedruk in aantal dae en in warmte eenhede. Dit is gevind dat geen definitiewe voorkeur gegee kan word aan een van die twee metodes nie, waarskynlik tengevolge van die feit dat die proef net op een plek geplant was.

Ten einde die gedrag van SA4 plante onder die invloed van verskillende temperatuurtoestande te bestudeer is saad gestuur na en geplant by Oxford (Engeland) en Arlington (Wisconsin, VSA). Die aantal dae en warmte eenhede wat by die twee plekke vir die periode van plant tot blom vasgestel is is vergelyk met dié wat op Bapsfontein verkry is.

Die resultate het gewys dat die aantal warmte-eenhede aansienlik minder verskil het van plek tot plek as die aantal dae.

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