Effects of Sowing Date on Growth and Yield of Wheat at Different Elevations in Jebel Marra Highlands under Rain-fed Conditions

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Abstract

A field experiment was conducted in Jebel Marra (Sudan) for two seasons, 2001-02 and 2002-03, on farmer's fields to investigate the effect of four sowing dates; early July, mid-July, early August and mid-August and two sites: Trongtonga at 2800 m and Gorlambang at 2300 m above sea level (a.s.l.) on the growth and yield of wheat. The experiment was carried out under rainfed conditions using three cultivars; namely, Debeira, El Nelein and a local cultivar (Donki). The results showed that the early sowing (July) produced higher grain and biomass yields, higher number of spikes/ unit area, more spikelets/spike and more seeds/spike compared to late sowing. Generally, the crop at the higher elevation site had greater biomass, higher grain yield and yield components. At low elevation the three cultivars reached anthesis and matured earlier than at higher elevation. El Nelein was the earliest to reach anthesis and produced the highest grain and biomass yields. The local cultivar (Donki) was the latest to flower and gave the lowest yield and yield components.

Introduction

Wheat is mainly grown in the Sudan under irrigation, during the winter months, north of latitude 13^{o}. Its production under rainfed conditions is limited to the western part of the country, particularly Jebel Marra Highlands, where altitude is greater than 2000 m a.s.l. and the temperatures during the rainy season (June-October) are conducive to wheat production. One of the requirements for obtaining high yield is the choice of the suitable sowing date, due to variations in weather conditions among seasons. Under rainfed conditions, therefore, the sowing date varies in the different locations and depends on rainfall pattern (frequency, duration and amount) as well as the maturity period of the specific wheat variety (Tanner, *e, al.* 1991). Thorne (1962) reported that early sowing increases dry matter production, leaf area, number of shoots and amount of nitrogen taken up by the crop. Furthermore, early sowing prolongs the duration of tillering, whereas late sowing decreases the yield (Ishag 1994). Early sowing appears to result in a long delay in ear initiation and, therefore, favours the formation of greater numbers of leaves on the main shoot (Kirby 1969). On the other hand, Ibrahim (1996) showed that

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delayed sowing in Northern Sudan is often associated with substantial losses in grain yield estimated up to 86% for short maturing varieties of 90 to 100 days.

High temperature is a major environmental constraint that limits wheat production in the Sudan. Nonetheless, considerable variability in bread wheat performance under heat stress conditions has been reported (Ageeb 1994). The deleterious effect of high temperatures during wheat growth in the Sudan may be mitigated by shortening irrigation intervals and also by growing the crop at higher altitudes, wherever topographic and other requirements are permissible, e.g. Jebel Marra region.

This work was, therefore, conducted to study wheat performance under rainfed conditions at high altitudes in Jebel Marra area, and to determine the most suitable variety and sowing date for that area.

Materials and methods

A field experiment was conducted for two seasons (2000-01 and 2002-03) to investigate the effect of sowing date and elevation on the performance of three cultivars of wheat; namely, Debira, El Nelein and a local cultivar (Donki). The sowing dates were: early July, mid-July, early August and mid-August. The experiment was conducted at two sites: Trongotonga (2800 m a.s.l.) and Gorlambang (2300 m a.s.l). in Jebel Marra Highlands. The experimental design was multi-factorial, completely randomized with four replicates. The plot size was 1.6x7.0 m, and the seed rate was 120 kg/ha. All plots were given phosphorus (46% P_2O_5) and nitrogen in the form of urea (46%N) at a rate of 40 kg/ha. The measured parameters were days to 50% flowering, plant height (cm), from the soil surface to the longest top leaf, and duration of grain filling. Yield components were number of spikes/ m^2, number of spikelets/spike, number of seeds /spike, 1000 seed weight, harvest index, biomass and final grain yield/hectare. Duncan Multiple Range Test was used to separate means (Gomez and Gomez 1984).

Results and discussion

Crop development

The number of days to 50% flowering was affected by sowing date. The time from sowing to anthesis was longer in the late sown crop by four days, as compared to the earliest sown, presumably due to relatively lower temperatures during anthesis of the late sown crop. Green *et al.* (1985) stated that crops sown at different dates pass through each developmental stage under different environmental conditions. Thus, the late sown crops in this study passed through cooler temperatures, and were associated with late flowering. El Nelein variety was significantly ($P \geq 0.05$) earlier and Donki was the latest to flower. The crops at the lower elevation flowered earlier than those at the higher altitudes by nine days. This may be attributed to the fact that the relatively higher temperatures of the lower sites ($3^{o}C$-$4^{o}C$ higher) had shortened the developmental stage from sowing to flowering (Table 6). On the other hand, Ishag and Mohamed (1995) reported that phasic development stages of wheat are affected by genetic and environmental factors. Sowing date had a great effect on the duration of grain filling. Late sown crops (early and mid-August) were severely affected by frost damage during the second and third weeks of November in both seasons and at the two sites. The duration of grain filling ranged between 32 and 37 days for early July sowing, to 15 and 14 days for sowing in mid-August at the high and the low elevation sites, respectively, in the first season (Tables 1-4). The duration of grain filling was two days longer for El Nelein, compared to Donki variety. No consistent response was found for the effect of the sowing date on plant height in both seasons and sites (Tables 1-4). It is likely that the relatively higher temperatures at the low elevation (Table 6) shortened the grain filling period by 4-5 days, and this is in accord with the findings of Fischer and Maurer (1976). Differences in plant height among the three cultivars were significant ($P \geq 0.05$). Donki was the tallest and El Nelein was the shortest in both seasons and at the two sites. The crops at the higher elevation were taller than those at the lower sites in both seasons.

Grain and Biomass Yields

The results in Tables 1, 2, 3 and 4 showed that the sowing date had a significant effect on grain yield in both seasons and locations, ranging in the first season between 4046 and 1303 kg/ha at high and 2862 and 435 kg/ha at the low elevations, respectively. Late sowing (mid-August) decreased grain yield by 67% and 84% for the high and low sites in the first season, respectively. The same trend was encountered in the second season. The decrease in grain yield was closely associated with lower 1000- seed weight with late sown crops, as was reported by Darwinkel *et al,* (1977). El Nelein variety outyielded both Debeira and Donki (Tables 1, 2, 3 and 4**).** This might be explained by the fact that El Nelein had greater number of spikes/m^2. This is in agreement with the findings of Harper *et al.* (1987) who reported that different spike populations can result from differences in the ability of cultivars to produce and sustain tillers. At the higher altitude (Trongtonga) the cultivar Donki gave the lowest yield when sown on 1st of July although this date was favourable for the other two cultivars. However, sowing on 1st of August resulted in similar yields (about 3 tons/ha) for all cultivars, and it was significantly lower than sowing at July 1st for El Nelain and Debeira (Fig.1a). The situation was different at Gorlambang site (lower altitude) where the yield was generally lower for all cultivars at the corresponding sowing dates (Fig.1b). Late sowing resulted in 71% to 82% reduction in biomass yield for the high and low elevations, respectively, in the first season (Tables 1 and 2). Differences between varieties in biomass production were not significant in the first season, whereas in the second season El Nelein gave significantly higher yields in both sites. Biomass yield of high elevation was greater than that of low elevation by 44% and 35% for the first and second seasons, respectively (Tables 1, 2, 3 and 4). On the other hand, differences between sowing dates were highly significant in biomass yield, which declined with delayed sowing. This was also reflected in the work of Kirby (1969) who confirmed that the potential for biomass yield in winter and spring wheat was reduced as sowing was delayed. While this finding was valid under a temperate climate, yet the relation of biomass with temperature was also demonstrated in the tropical climate of Jebel Marra.

Yield Components

Delayed sowing decreased the number of spikelets/spike, number of seeds/spike, number of spikes/m^2 and 1000 seed weight. Similar results were obtained by Ishag (1994). The number of spikelets/spike was not affected by elevation (Fig.2a and b). However, El Nelein had a higher number of spikelets/spike, seeds/spike and spikes/m^2

and a higher 1000- seed weight (Tables 1, 2, 3 and 4). Yield components at the higher elevation were greater than those at the lower elevation. The rate of crop development under cooler conditions of the higher elevation led to development of more spikelets, and this was accompanied with an increase in grain yield. Similar effects of altitude on wheat development and yield in Ethiopian Highlands were reported by Gorfu *et al,* (2003). Following the same trend for growth and yield, late sowing resulted in decrease of the harvest index, which was 38% and 41%, for early July sowing, and decreased to 22% and 15% for mid-August sown crop, respectively, in the first season (Tables 1- 4). Differences in harvest index between varieties were significant in both seasons and sites. El Nelein had the highest harvest index, followed by Debeira. Differences in the harvest index for the crops grown at the two elevations were not consistent (Tables1, 2, 3 and 4).

Conclusions

It can be concluded that early sowing in July is optimum at elevations of 2300 and 2800 m (a.s.l.) at Jebel Marra locations. However, at the higher elevation, the sowing date can be extended to the first week of August. El Nelein cultivar gave highest yield for both locations and sowing dates of July and August than the other cultivars. The rainy season sowing (July-August) in Jebel Marra Highlands allows an additional sowing season for wheat in the Sudan by virtue of relative decrease in summer temperatures due to elevation and rainy season.

Recommendations

- Early sowing of July is appropriate for both locations.
- At the higher elevation of 2800 m, it is possible to delay the sowing date to the fist week of August.
- The variety El Nelein is the most suitable in Jebel Marra at both elevations.

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Table 1. Effect of sowing dates on growth and yield of wheat varieties grown at different elevations in Jabel Marra highlands-Trongotonga site, season 2000-01.

Sowing date	Flag leaf area (cm^2)	Days to 50% flowering	Duration of grain filling (days)	Plant height (cm)	No. of spikelet s/spike	No. of seeds/ spike	1000 seed wt.(g)	No. of spike s/m^2	Harvest index %	Biomass yield (kg/ha)	Grain yield (kg/ha)
SD1	19.4	73	38	89	18	35	41	420	38	11101	4047
SD2	16.9	74	39	86	16	32	37	373	36	8713	2990
SD3	16.6	74	29	81	15	32	30	367	28	8095	2134
SD4	16.1	77	15	84	16	31	25	307	22	615	1303
S.E.±	0.86	0.19	0.20	2.1	0.61	1.5	1.7	32	1.4	781	234
Variety											
Debeira	17.1	75	27	79	16	33	32	352	30	8636	2686
ElNelein	18.9	97	29	74	17	34	36	371	35	8309	2775
Donki	15.8	83	27	102	15	31	32	376	29	8607	2395
S.E.±	0.74	0.16	0.17	1.8	0.53	1.3	1.5	28	1.2	676	202
Site	17.3	75	28	85	16	33	33	366	31	8517	2619

SD1= Early July SD2= Mid July SD3= Early August SD4= Mid August

Table 2. Effect of sowing dates on growth and yield of wheat varieties grown at different elevations in Jabel Marra highlands-Gorlambang site, season 2000-01.

Sowing date	Flag leaf area (cm^2)	Days to 50% flowering	Duration of grain filling (days)	Plant height (cm^2)	No. of spikelets/ spike	No. of seeds/ spike	1000 seed wt.(g)	No. of spikes/m^2	Harvest index (%)	Biomass yield (kg/ha)	Grain yield (kg/ha)
SD1	17.8	67	30	81	17	29	40	332	41	8431	2862
SD2	19.0	68	30	87	19	31	41	397	35	8245	2122
SD3	11.1	69	26	77	16	27	30	219	25	3394	837
SD4	7.5	72	15	65	14	24	24	173	16	2462	435
S.E.±	0.54	0.21	0.19	0.61	0.66	1.43	1.66	26	1.3	596	187
Variety											
Debeira	13.7	68	25	67	17	28	33	275	30	4726	1539
ElNelein	14.7	63	28	73	17	28	37	276	30	4659	1733
Donki	13.0	0.17	0.21	26	78	17	28	31	277	4805	1468
S.E.±	0.47	0.17	0.21	0.53	0.57	1.24	1.4	23	1.1	516	162
Site	13.8	69	26	78	17	28	34	276	29	4730	1568

SD1= Early July SD2= Mid July SD3= Early August SD4= Mid August

Table 3: Effect of sowing dates on growth and yield of wheat varieties grown at different elevations in Jabel Marra highlands-Trongotonga site, season 2002-03.

Sowing date	Flag leaf area (cm^2)	Days to 50% flowering	Duration of grain filling (days)	Plant height (cm)	No. of spikelets/ spike	No. of seeds/ spike	1000 seed wt (g)	No. of spikes/ m^2	Harvest index (%)	Biomass yield (kg/ha)	Grain yield (kg/ha)
SD1	17.9	70	36	86	18	36	40	340	39	6465	2567
SD2	18.6	71	37	86	16	36	39	334	39	6577	2756
SD3	16.0	74	28	81	15	31	27	316	24	5022	1289
SD4	14.5	76	15	79	16	28	21	280	15	2647	406
S.E.±	0.82	0.15	0.23	0.77	0.61	0.34	0.35	9	0.51	304	119
Variety											
Debeira	16.9	77	26	75	16	33	31	238	29	5515	1896
ElNelein	17.3	68	30	73	17	36	34	334	32	6041	2115
Donki	16.0	78	28	102	16	29	30	290	27	3978	1252
S.E.±	0.25	0.13	0.19	0.62	0.21	0.30	0.31	8	0.53	264	103
Site	16.7	73	28	83	16	33	32	317	29	5172	1754

SD1= Early July SD2= Mid July SD3= Early August SD4= Mid August

Table 4. Effect of sowing dates on growth and yield of wheat varieties grown at different elevations in Jabel Marra highlands-Gorlambang site, season 2002-03

Sowing date	Flag leaf area (cm^2)	Days to 50% flowering	Duration of grain filling(days)	Plant height (cm)	No. of spikelets/ spike	No.of seeds/ spike	1000 seed wt. (g)	No. of spikes/ m^2	Harvest index (%)	Biomass yield (kg/ha)	Grain yield (kg/ha)
SD1	14.5	63	32	78	17	30	39	306	41	4668	2063
SD2	15.7	64	32	75	17	29	39	285	41	4053	1778
SD3	10.4	65	27	69	14	26	30	225	25	3032	757
SD4	6.8	65	14	59	13	24	22	170	17	1597	294
S.E.±		0.20	0.15	1.61	63	0.30	0.31	11	1.1	202	132
Variety											
Debeira	12.5	61	24	69	16	27	31	221	31	2228	1156
ElNelein	12.0	60	27	65	16	28	36	269	33	4147	1499
Donki	11.0	72	23	75	15	27	31	250	28	2529	1015
S.E.±	0.17	0.17	0.13	1.59	0.48	0.26	9	0.9	0.9	234	114
Site	11.8	64	24	70	15	24	33	247	31	3339	1123

SD1= Early July SD2= Mid July SD3= Early August SD4= Mid August

Fig.1: Response of wheat yield to sowing dates

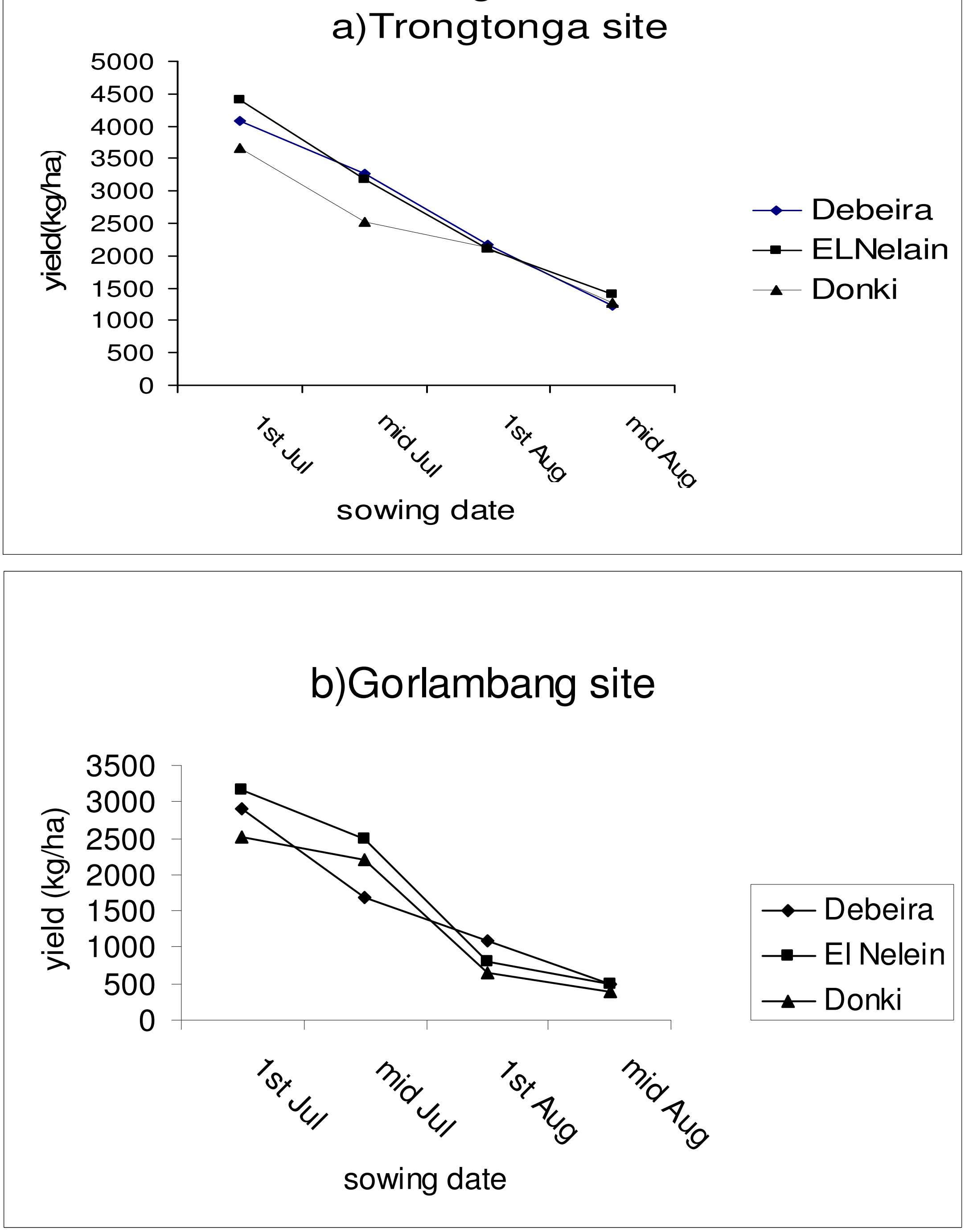
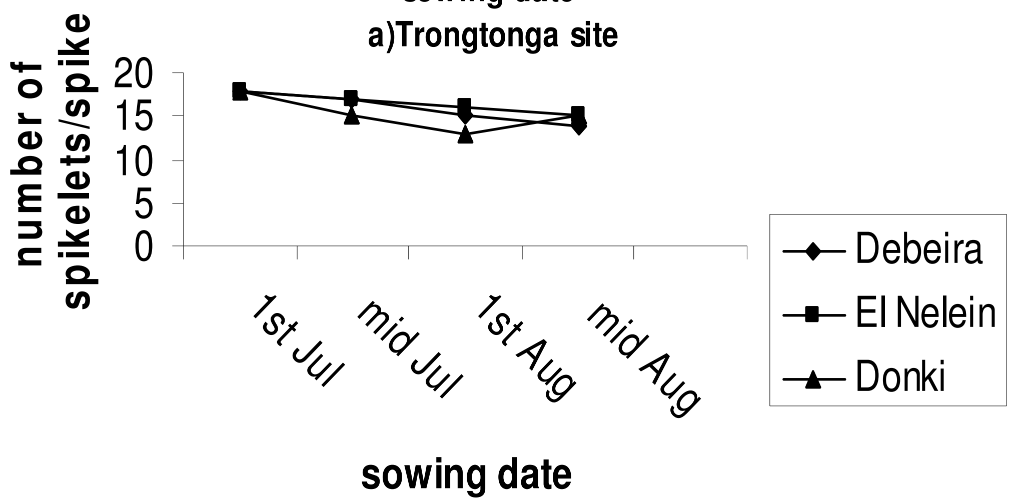


Fig.2: Response of number of spikelets/spike of wheat to sowing date

a)Trongtonga site



b)Gorlambang site

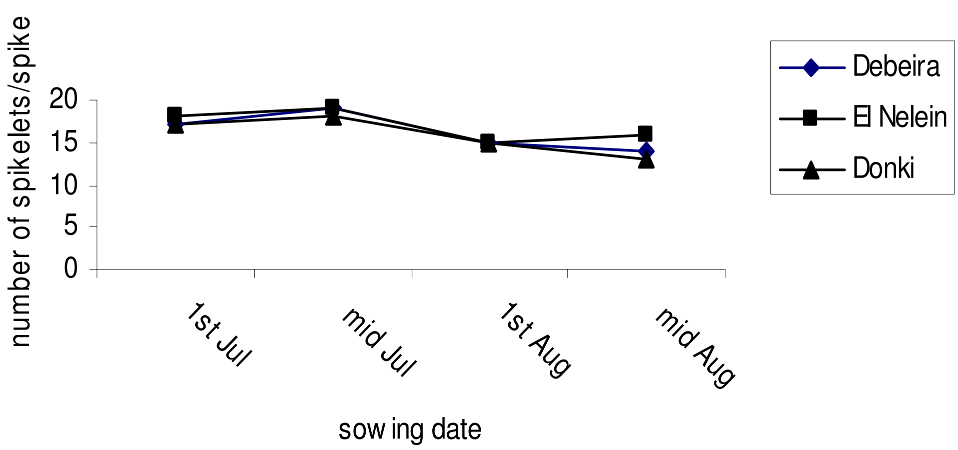


Table 5. Effect of sowing date on grain yield (kg/ha) of different wheat cultivars during 2000-01 (a) and 2002-03 (b) seasons

a- Trongtonga site season 2000-01

Varieties	Sowing dates (SD)				
	SD1	SD2	SD3	SD4	Mean
Debeira	4080	3272	2168	1219	2686b
El Neilain	4407	3185	2100	1408	2775a
Donki	3652	2511	2135	1282	2395a
Means	4047[a]	2990[b]	2134[a]	1303[d]	2619

S.E. for SD = ± 234
S.E. for V = ± 202, S.E. for SDxV= ± 405

Gorlambang site 2000-01 season

Varieties	Sowing dates (SD)				
	SD1	SD2	SD3	SD4	Mean
Debeira	2910	1680	1081	486	1539[a]
El Neilain	3161	2491	792	490	1733[a]
Donki	2516	2194	637	383	1432[a]
Means	2862[a]	2122[b]	837[c]	453[d]	1568

S.E. for SD = ±187
S.E. for V = ±162, S.E. for SDxV = ± 324

Varieties	Sowing dates (SD)				
	SD1	SD2	SD3	SD4	Mean
Debeira	2557	2889	1635	505	1896[b]
El Neilain	3248	3180	1495	535	2115[a]
Donki	1896	2200	734	178	1252[c]
Means	2567[a]	2756[a]	1289[b]	406[c]	1754

S.E. for SD = ± 119
S.E. for V = ± 103 , S.E. for SDxV= ± 206

Varieties	Sowing dates (SD)				
	SD1	SD2	SD3	SD4	Mean
Debeira	2098	1424	790	311	1156[b]
El Neilain	2309	2202	1099	386	1499[a]
Donki	1784	1707	384	186	101[5c]
Means	2063[a]	1778[b]	757[c]	294[d]	1223

S.E. for SD = ± 132
S.E. for V = ± 114, S.E. for SDxV = ± 228

Means followed by the same letter(s) are not significantly different at 0.05 level of probability according to DMRT.
SD1 = Early Jult, SD2 = Mid-July, SD3= Early August, SD4 = Mid-August

Table 6. Monthly rainfall record (mm) at Trongtonga and Gorlambang sites (2000, 2001and 2002).

Site / Month	Trongtonga Site			Gorlambang Site		
	2000	2001	2002	2000	2001	2002
April	19.5	10.5	-	-	50.0	9.0
May	58.5	72.5	59.0	25.0	17.0	14.5
June	114.5	124.5	120.5	131.5	65.5	98.5
July	248.5	229.0	277.0	187.0	148.0	197.0
August	306.0	267.0	388.0	276.5	261.5	257.5
September	62.0	51.0	177.5	85.5	63.5	107.5
October	15.0	-	27.0	-	21.0	11.0
Total	824.0	754.5	1049.0	705.5	626.5	695.0

Table 7. Mean air temperature (^{0}C) at Trongtonga and Gorlambang sites (2000, 2001 and 2002).

Site / Month	Trongtonga Site			Gorlambang Site		
	2000	2001	2002	2000	2001	2002
July	17.2	18.7	18.3	23.3	22.3	24.5
August	16.7	16.5	17.5	21.6	20.2	23.0
September	17.5	17.0	17.8	20.0	19.0	21.3
October	18.0	18.0	19.0	21.5	21.5	20.7
November	15.4	16.5	17.3	19.0	18.9	19.9
December	14.0	15.3	16.3	17.6	17.8	17.5
Mean	16.5	17.0	17.7	20.5	20.0	21.1