THE EFFECT OF IRRIGATION ON DRY MATTER AND NUTRIENT ACCUMULATION IN SOYBEAN (GLYCINE MAX (L.) MERRILL) PLANTS

by

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INTRODUCTION

Growth, development and reproduction of plants is controlled by the forces of genetics and the environment. Though the potential yield of a crop is determined by the genetic makeup of the crop, factors of the physical environment such as soil characteristics, light, moisture and aeration affect the degree it expresses its inherent capacity. Physiological stresses during the ontogeny of the plant adversely affect the normal functioning of plant processes. The magnitude of the effects depends upon the nature of the stress, plant parts affected, and the stage of development at which the stress occurred.

The water content of the rhizosphere plays a vital role both in the absorption and the translocation of plant food elements. Water deficits at the time of flowering and pollination can irreversibly damage plant processes and unfavorably affect final yield. If metabolism is brought to a standstill, life, as we know it, would be impossible because of the complete absence of water. Therefore, water is a major parameter in the overall reproductive development of most agronomic and horticultural crops.

Irrigation studies with soybeans have been geared to the application of water, with little attention to the actual time of application and the requirements of the growing crop.

The characterization of the process of dry matter accumulation of many crops like, corn, sorghum, etc. has been done by growth analysis, but little work has been done pertaining to the dry matter accumulation in soybeans.

At least 16 elements are required for optimum growth of plants. Water and the other nutrients regarded as essential for higher plants are complexly intertwined in their effects on growth and reproduction. All are essential and yet so interdependent that one can not be considered without the others during the transport from the soil to the roots, absorption by the roots, and translocation in the growing plant. Nutrients are required for the formation of carbohydrates that provide energy reserve, enzymes and catalysts that regulate metabolic activity. They are components of nucleic acids that direct plant processes. They are also necessary for maintaining osmotic balance and absorption of ions from the soil solution.

This study was undertaken to investigate the pattern of concentration of some essential elements in the plant and the changes in the pattern attributable to water application.

The level of available soil moisture depletion after which one has to consider irrigation for maximum dry matter production is a useful criterion in irrigation. Knowledge of the amount and the trend of nutrient accumulation in the different plant parts will shed light on the actual stage of development at which accumulation is critical. Moreover, knowledge of the concentrations in the whole plant and its parts would facilitate the diagnostic problems associated with nutrients.

LITERATURE REVIEW

There are conflicting opinions as to the effect of irrigation on soybean production. Dorneana, Blejan, and Dragnea (1970) reported that fertilizer alone gave significantly less yield than when coupled with irrigation. Matson (1964) stated that the response of soybeans to irrigation has often been disappointing to growers. Frequently they have found that the increase in yield did not pay the cost of irrigation. Thompson and Caviness (1969) reported that yields of soybeans were consistently increased by irrigation and continuous irrigation did not decrease yield. Khan and Ali (1969), after studying water requirement of soybeans, reported a significant increase in the number of pods and seed yield when 27 acre-inches of irrigation water was used. Dimitrov (1969) and Shih and Su (1970) showed that irrigation increased the yield of soybeans. Henderson (1971) observed that soybeans did not respond to supplemental irrigation and inoculation. Irrigation of soybeans in Nebraska in 1966 reduced yield. The dryland out yielded the irrigated crop (Randolph 1967). Dimitrov (1969) reported that irrigation decreased the protein content and increased the fat content and nitrogen free extracts of the seeds.

Mississippi Delta studies (Matson 1964) show that it made little difference in soybean yield whether water was applied when the moisture level at the center of the root zone was reduced to 75 percent available capacity, or permanent wilting point. Spooner (1961) observed that when soil moisture was kept at about 50 percent, irrigation gave a significant increase in yield. Khazakhastan studies (Goryunov and Ogryzkova, 1964) indicated that all physiological characteristics were favorable and crop yield was high when the moisture in the rhizosphere was maintained during the vegetative period at not less than 80 percent of the field water capacity. The maintenance of soil moisture capacity throughout the vegetative period provides the best conditions for plant growth and high yields of soybeans. Uklein (1961) concluded that irrigation during crop emergence and at flowering and filling of the beans was also an important factor in increasing yield. Henderson (1971) noted that depth of rooting and thoroughness of root ramification are important factors in determining the quantity of water which may be depleted before irrigation is required. Apparently the common cause of reduced yield through lack of moisture is in reduction of seed weight. Other yield components were not affected.

Rodgornaya (1970) after studying the relationship of rainfall during the various growth phases and seed yield of soybeans, observed a significant correlation between seed yield and amounts of rainfall during the periods of flowering and seed formation.

Mulalic (1968) indicated that in dry years lack of available water during flowering and seed setting caused a considerable decrease in yield. Brown and Chapman (1960) and Taterfield (1966) concluded that the critical period in the growth of soybeans from the water standpoint seems to be the pod filling stage. According to Matson (1964), irrigation before fruiting was not beneficial. Irrigation from bloom to one month before harvest was nearly as effective as irrigation throughout the season. Peters and Johnson (1960) concluded that yield would not be reduced by withholding irrigation until plants begin to bloom and by discontinuing irrigation one month before harvest.

Masujima (1964) reported that dry matter production was greater at the higher soil moisture level, but its calcium percentages were unaffected by soil moisture level. Kono (1969) and Henderson and Kamprath (1971) reported that despite variations in growing conditions, dry matter accumulation reached a peak each year at around 110 to 120 days after planting. The rate of accumulation in both vegetative portions and total plant later decreased due to leaf fall.

Hanway and Weber (1971) reported that rapid dry matter accumulation in the seeds began at different times after stage five in the different varieties, but the rate of accumulation was similar in all varieties and both years (1963 and 1964). They also reported an increase of 108 kg/ha per day. Other plant parts lost weight after stage eight or nine. At maturity, dry matter consisted of 28% leaves, 15% fallen petioles, 17% stems, 11% pods, and 29% beans. The dry weight of leaves and petioles on the plant attained a maximum at stage six and remained constant through stage eight. By 20 days after stage five, the stems had attained a dry weight equivalent to the stem dry weight at maturity, indicating an accumulation of soluble carbohydrates in the stems that was translocated to developing seeds near stage nine.

Kipps (1970) observed that the approximate composition of a 50 bushel per acre soybean crop is 7000 pounds of dry matter per acre including roots. Out of the total, the essential nutrients' weight amounted to 6,844 pounds. The difference is made up of nonessential elements such as silicon, aluminum, barium, sodium, strontium, etc.

In 50 genotypically diverse varieties, Arora, Sandra, and Mehrotra (1970) observed a significant correlation between seed yield and mineral matter ($r = 0.395$). Ohlrogge (1960) observed a close correlation between yield and the amount of nitrogen accumulated throughout the life cycle of the plant.

Grain yield was determined by the number of pods retained by the plant, and this in turn was determined by the level of nitrogen available during the bloom period. An examination of numerous data (Ohlrogge 1960) suggests an optimum range for the total tops of between 0.25 and 0.45 percent phosphorus for the prebloom stage. Field grown soybeans showed 0.31, 0.09 and 0.24 percent phosphorus for leaves, stems and total tops, respectively. According to Harper (1971), 40 bushels of soybean seed will contain approximately 16 pounds of phosphorus and 50 pounds of potassium.

Jones (1967) indicated that nutrient element concentration changes with time. Large changes in concentration generally occur early in the initial stages of growth and usually immediately following pollination.

Hanway and Weber (1971) pointed out that nitrogen in the vegetative plant parts (averaged over position on the plant), for all leaves, petioles, and stems of nodulating plants without nitrogen fertilizer, usually decreased as the plant developed during the season. Younger plant parts had higher nitrogen than did older plant parts. Hanway and Weber (1971), and Ohlrogge (1960) reported that nitrogen, phosphorus and potassium concentration in each plant part, except the seeds, usually decreased as the season progressed. Percent nitrogen in total tops generally declined from the seedling stage and leveled off shortly after full bloom. Phosphorus concentration increased during the first 30 days after emergence, peaked at initial flowering, declined until mid-pod fill, and leveled off through the remaining period of growth. At maturity 80-85 percent of the phosphorus in the plant was in the seed. Percent potassium increased slightly from the seedling stage until full bloom and then declined. Calcium concentration increased until initial flowering, then declined and leveled off during later growth stages.

Magnesium content decreased gradually from seedling stage through the green bean stage. The concentration of micro-nutrients generally declined from the seedling stage through the green bean stage.

Total accumulation of nitrogen, phosphorus and potassium in the plant parts followed patterns similar to that of dry matter. Hanway and Weber (1971) reported that rates of accumulation were slow early in the season, but became rapid later until stage five where it became constant until stage nine. About 80 percent of the nutrients were accumulated between these two stages. Approximately half of the nitrogen, potassium and phosphorus of the seeds was translocated from the other plant parts.

EXPERIMENTAL METHODS

On May 15, 1971 and on May 18, 1972 'Calland' soybeans were planted in plots 14 m long and 5 m wide and in rows 61 cm apart on Muir silt loam. The main plots consisted of three available soil moisture depletion levels (20, 40 and 60%) and were stripped across the experimental area. These levels indicate the amount of soil moisture depleted from the root zone (0-1.5 m) before irrigation water was applied. The subplots were three stages of growth at which water was applied. These were the time periods; vegetative development to maturity, flower formation to maturity and pod-filling stage to maturity. In each main plot a control plot which was not irrigated was included and the treatments were replicated four times. Since the design employed was not exactly a split plot, the results obtained are subject to bias.

The water status of the soil was determined by neutron probe.

Starting from fifteen days after emergence, samples of ten plants, for the first three sampling dates and five plants thereafter, were taken at an interval of fiteen days. In both years, the samples were dried at 63°C for five days. Total dry matter, excluding roots, was quantified after drying. In 1971, pods and seeds were separated, but the stems and the leaves were considered together. In 1972, however; stems, leaves, pods and seeds were separately studied.

The dried plant material was ground thoroughly enough to pass through a 20 mesh seive. Representative subsamples were taken from each sample and oven dried at 70°C for 24 hours.

Samples taken on July 13, August 10 and September 6, in 1971 and on July 17, August 14 and September 9 in 1972, were used for nutrient determination.

Nitrogen was determined by Micro-Kjeldahl Steam Distillation Method. Perchloric Acid Wet Ashing Method (after Jackson, 1958) was employed to analyze phosphorus, potassium, calcium, magnesium, iron, copper, manganese and zinc. Phosphorus was determined by using Jackson's Vanado-molybdate Phosphoric Acid Yellow Method in Nitric Acid System. Magnesium, calcium and the micro-elements were assayed using Perkin-Elmer Spectrophotometer. Potassium was determined by using flame photometer. Copper, iron and manganese data for 1972 were not reliable and therefore are not included in the paper.

Agronomic measurements, such as plant height (cm), lodging score (1 to 5, where 1 stands for all plants erect and 5 means 100 percent of plants prostrate) and dates of maturing (95% of pods brown), and seed yield were taken at maturity.

Irrigation data for the two crop seasons are given in the appendix (Tables 23 and 24).

RESULTS

Dry Matter Accumulation

Figure 1 shows the pattern of the accumulation of dry matter. In both seasons the dry matter accumulated at an increasing rate until the fourth sampling date, July 13 in 1971 and July 17 in 1972. After this period the dry matter accumulated at essentially a constant rate. Peak accumulation of total dry matter was attained in early September.

Although the magnitude of dry matter accumulation was greater at the 20 PAWD (percent available water depletion) level, only two of the PAWD level differences, September 9 and July 17, 1972 were significantly higher at the 20 PAWD level than the other two levels. The time of application did not affect the amount of dry matter produced (Table 1).

The breakdown of the total dry matter into stems, leaves and pods in 1972 revealed that the dry matter of the parts did not behave like the total dry matter (Appendix Table 25). Samples taken on July 17 produced more dry matter in leaves at the 20 PAWD level. Furthermore, the average dry matter was higher for irrigation during flowering than the remaining treatments. On the average there was more dry matter in plants which received water during podding than those irrigated during the vegetative stage. The least amount of dry matter was produced by the control plot. The dry matter in samples taken on August 14 followed a similar pattern (Table 1). Time of application showed the same trend on the dry matter accumulated in the stems (Appendix Table 26), but the level of water applied did not significantly affect the dry matter accumulation. No significant differences were observed in the mean differences of the dry matter in leaves, stems or pods for the succeeding sampling dates.

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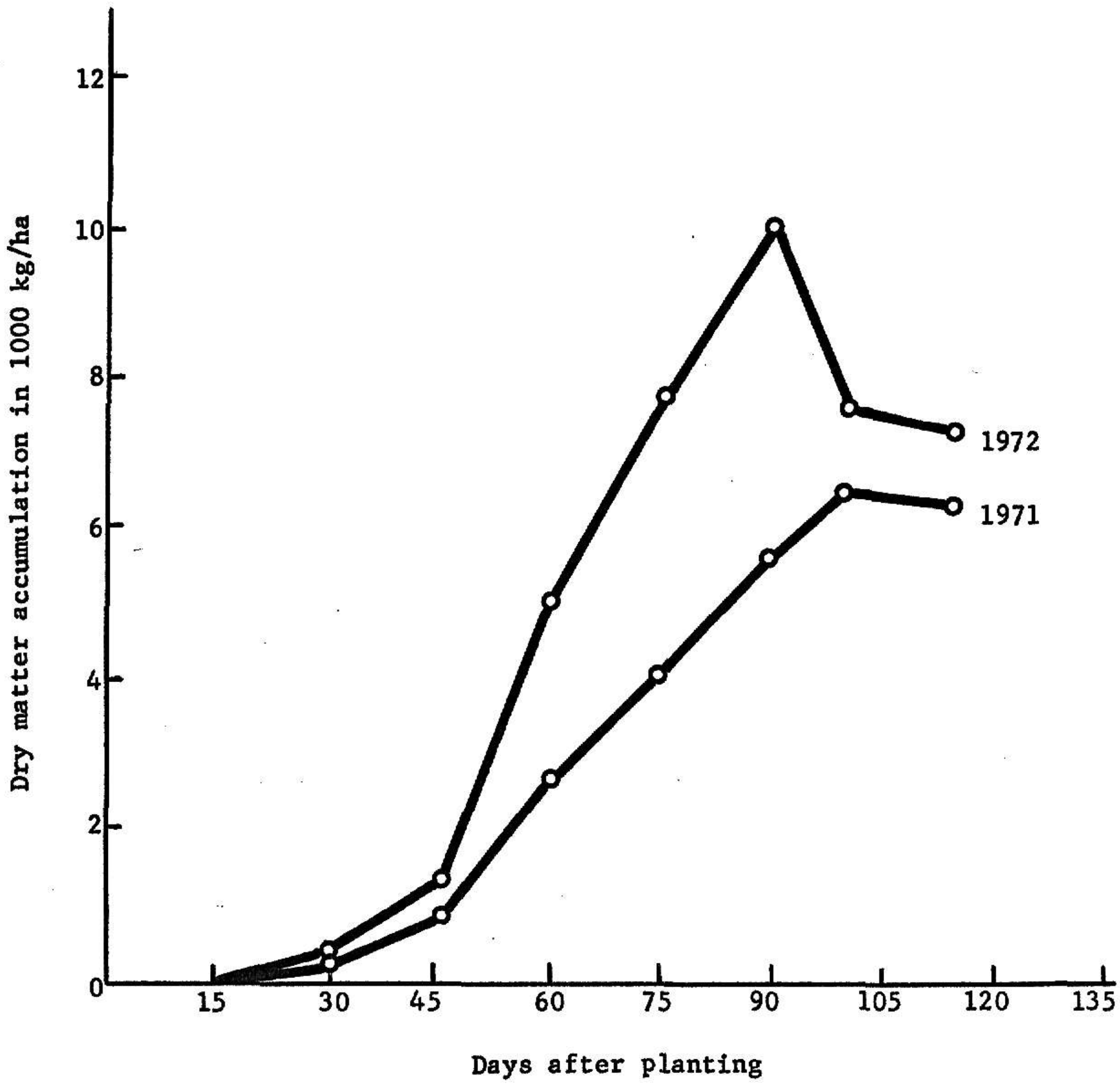

Figure 1. Dry matter accumulation in 1971 and 1972.

Table 1. The influence of percent available water depletion and stage of development on dry matter accumulation (kg/ha) in 1971 and 1972.

1971						1972			
Sampling dates	Control	Vegetative	Flowering	Podding	Sampling dates	Control	Vegetative	Flowering	Podding
				20 PAWD					
June 1	34	36	36	32	June 5	67	62	56	48
June 15	284	244	244	316	June 19	332	396	455	399
June 29	844	798	798	825	June 30	1676	1294	1246	1355
July 13	3241	2490	2204	2839	July 17 1/	5429	5475	6037	7301
July 27	6043	5049	5049	4117	July 31	7173	8078	7283	7277
Aug. 10	6227	5365	5365	6219	Aug. 14	8999	9457	14104	10930
Aug. 27	4910	5673	5673	8472	Aug. 28	7226	7558	6543	7556
Sept. 6	6811	6530	6530	9648	Sept. 9	6289	6699	6091	5788
				40 PAWD					
June 1	35	38	38	35	June 5	57	59	62	51
June 15	228	238	252	292	June 19	388	351	453	413
June 29	884	1018	892	804	June 30	1157	1302	1262	1323
July 13	2478	2670	2237	2847	July 17	4090	5049	5710	4221
July 27	3490	3635	4607	3053	July 31	5852	7486	6760	7159
Aug. 10	6107	5285	6294	5705	Aug. 14	10023	9216	9656	9184
Aug. 24	7017	6134	5311	7446	Aug. 28	6444	6934	6417	6760
Sept. 6	5150	6490	5250	3857	Sept. 9 2/	5834	6059	8402	7068
				60 PAWD					
June 1	38	35	38	38	June 5	51	56	62	54
June 15	281	271	279	295	June 19	496	442	498	466
June 29	1079	1039	892	999	June 30	1296	1428	1355	1387
July 13	2250	2933	3053	2620	July 17	4336	4442	5333	4569
July 27	3573	4130	3854	3335	July 31	6385	7395	7984	7872
Aug. 10	5009	5665	5552	4762	Aug. 14	9018	10009	11131	9757
Aug. 24	5793	4058	4821	6195	Aug. 28	5617	7210	7162	6988
Sept. 6	3951	5785	4535	4741	Sept. 9	7671	6526	7666	6990

1/ $LSD_{.05} = 680$

2/ $LSD_{.05} = 52$

Comparison of the dry matter produced in both years (Table 1) showed that the total amount of dry matter produced in 1972 was more than that produced in 1971. The periodic variation in the content of dry matter was about the same in both years.

Agronomic Performance

Irrigation had a significant effect on the agronomic characteristics studied. The final seed yield from the treated plots was consistently higher at the 20 PAWD level in 1971 (Figure 2) and higher from podding than the other treatments. The control treatment was significantly lower in yield than the other treatments. In 1972 (Figure 3), time of application had a significant effect on the yield produced. The check plots produced lower yield than the plots to which water was applied. The average yield for two years was higher at the 20 PAWD level than the other two levels ($LSD_{.05}$ = 66.8). There was a significant year by depletion interaction ($LSD_{.05}$ = 91.8). The three level interaction (year, depletion and stages) was also significant ($LSD_{.05}$ = 138.1). The average difference in yield between the 40 PAWD level was not significant.

The difference in seed weight between the depletion levels was significant in 1971 (Table 2). The 20 PAWD level produced heavier seeds than the 40 or the 60 PAWD levels. Time of application significantly affected seed weight. Seeds resulting from early water application were heavier than those obtained from plots irrigated during and after flowering. The seeds from the control plot were the lightest in weight.

Although the 100 seed weight appears to be low for the 20 PAWD level in 1972, the difference was not significant.

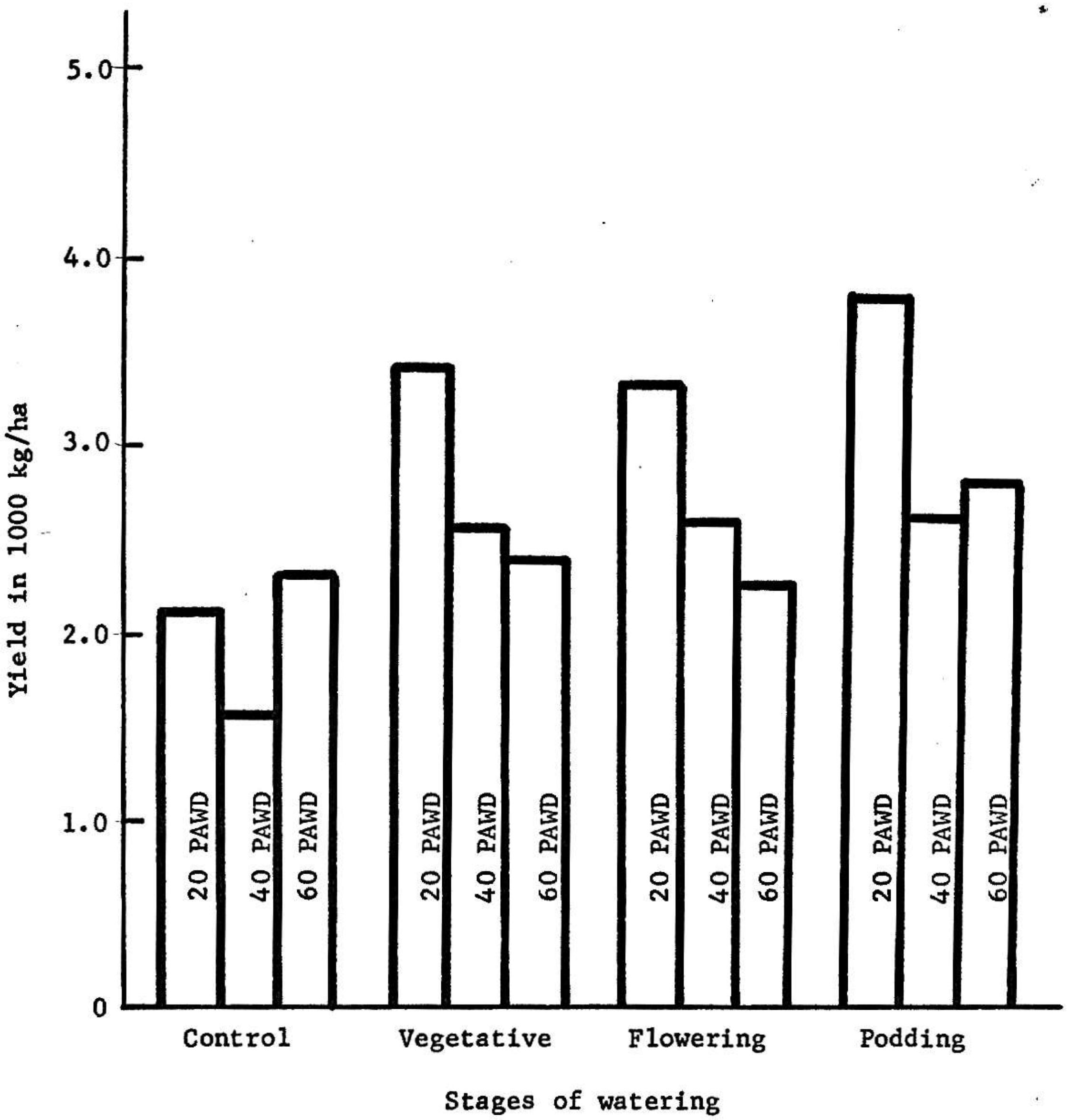

Figure 2. Total seed yield (kg/ha) at different available water depletion levels and stages of watering (1971).

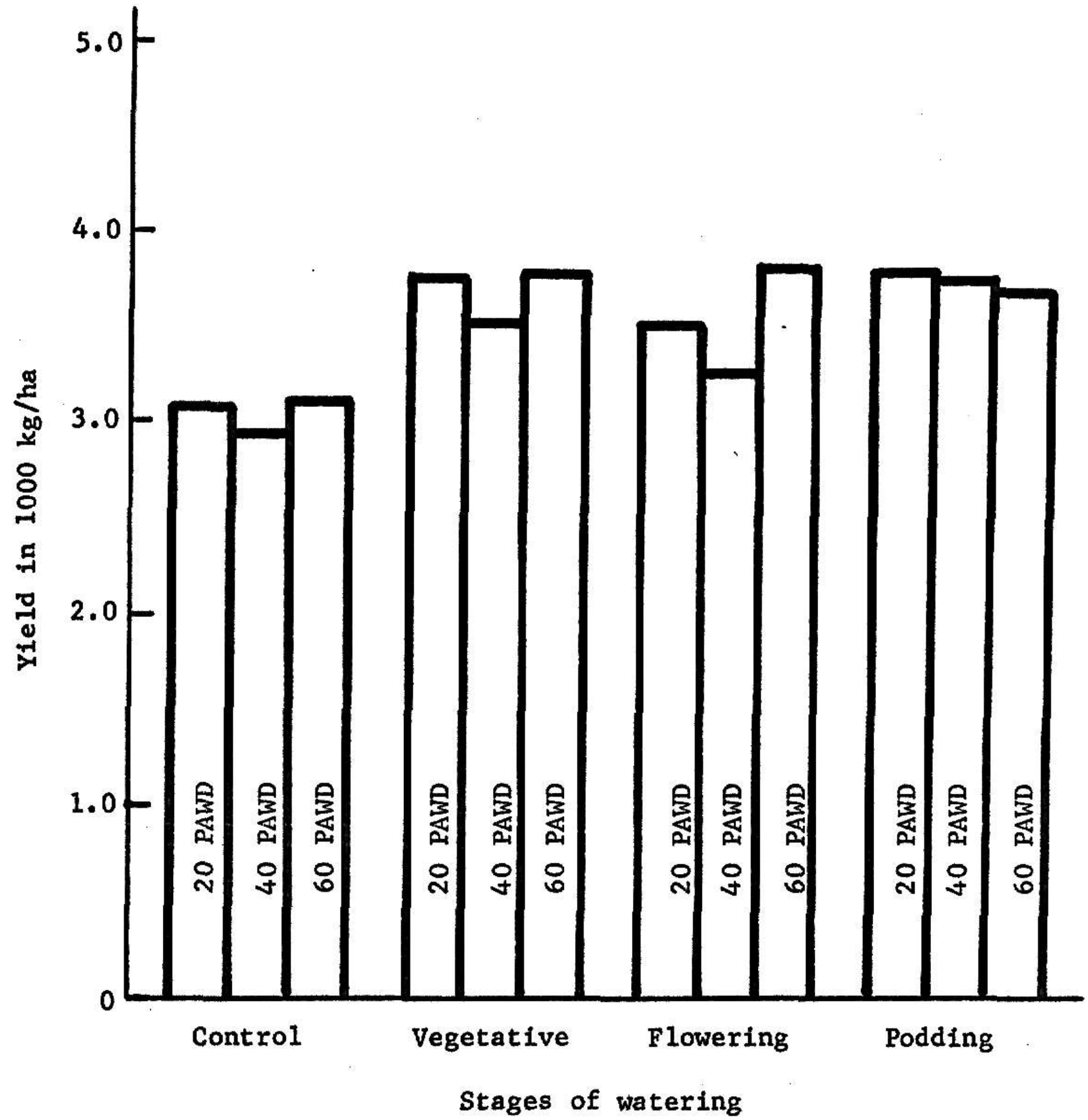

Figure 3. Total seed yield (kg/ha) at different available water depletion levels and stages of watering (1972).

Table 2. Effect of water application on agronomic performance.

	PAWD			Stages of Water Application			
	20	40	60	Control	Vegetative	Flowering	Podding
1971							
Yield (kg/ha)[1]	2998	2304	2496	2036	2904	2640	2818
100 Seed wt. in gm[2]	14.7	11.8	11.9	11.4	13.9	12.7	13.2
1972							
Yield (kg/ha)[3]	3508	3366	3571	3023	3627	3534	3742
100 Seed wt. in gm	16.7	17.6	17.5	17.0	17.4	17.6	17.0
Height in cm[4]	127	128	126	120	130	131	128
Lodging[5]	2.5	2.0	1.9	1.3	2.8	2.4	2.0

	$LSD_{.05}$
[1] Comparison of two depletion level means	78
Comparison of two stage means	77
[2] Comparison of two depletion level means	1.7
Comparison of two stage means	1.0
[3] Comparison of two stage means	271
[4] Comparison of two stage means	3
[5] Comparison of two depletion level means	0.3
Comparison of two stage means	0.3

The effect of water on lodging was related to the number of times water was applied (Table 2). The lodging score was highest for the plots that received water during the vegetative stage. This was followed by plots watered starting from blooming. Relatively fewer plants lodged from the plots irrigated at and after pod-filling stage. The lodging score was significantly lower for the control plots than the treated plots. More plants lodged at the 20 PAWD level. There was no difference in the proportion of plants lodged between the 40 and the 60 PAWD levels.

Plant height measurements (Table 2) indicated that the control plots were significantly shorter than those which received water sometime during the growing period. No appreciable differences in height were observed among the depletion levels or among the time periods at which water was applied. Plants that received water starting from the time of flowering were taller, but the height differences were not significant.

Nutrient Accumulation

The accumulation pattern of the nutrients studied parallels that of dry matter accumulation. The nutrients decreased in magnitude after peak accumulation. The decline in accumulation of nutrients in the vegetative parts was associated with the simultaneous increase of nutrients in pods and later in seeds.

Tops (excluding pods and seeds). For the samples taken on July 13, 1971 (Table 3), with the exception of zinc, all interactions between depletion levels and time of application of water were significant. At the 20 PAWD level the control plants absorbed more nutrients and at the 40 PAWD level this was reversed and the control plants absorbed less than the other treatments.

Table 3. Total dry matter and nutrient accumulation (kg/ha) in leaves and stems on July 13, 1971.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	76.17	76.55	79.91	76.34	79.01	74.29	80.54
Phosphorus	6.28	6.68	6.93	6.51	6.71	6.54	6.77
Potassium[1]	56.45	49.29	58.26	53.31	56.82	54.24	54.25
Calcium	21.63	20.02	19.56	20.21	20.38	19.25	21.79
Magnesium	6.89	6.97	7.57	7.17	7.23	6.82	7.36
Zinc	0.097	0.088	0.096	0.090	0.095	0.088	0.103
Copper[2]	0.028	0.024	0.019	0.025	0.022	0.024	0.025
Iron[3]	0.593	0.550	0.488	0.618	0.446	0.514	0.596
Manganese	0.121	0.123	0.122	0.127	0.119	0.115	0.127
Dry Matter	2700	2560	2740	2660	2700	2500	2800

	$LSD_{.05}$
[1] Comparison of two depletion level means	4.54
[2] Comparison of two depletion level means	0.003
[3] Comparison of two depletion level means	0.125

Potassium, copper and iron accumulation patterns were affected by the depletion levels (Table 3). The 40 PAWD level accumulated less potassium than the other two levels. More copper accumulation took place at the 20 PAWD level than the 40 PAWD level, which in turn accumulated more than the 60 PAWD level.

The 20 PAWD level accumulated more iron at the August 10 and copper at the September 6 sampling dates than the other levels (Tables 4 and 5). There were no significant stage by depletion interactions.

Pods. The accumulation of calcium, zinc, copper, iron and manganese was significantly greater at the 20 PAWD level than at the other levels (Table 6 and 7). At this stage of growth, water application had a significant effect on all the micro-elements considered. No macro-element, except calcium, was affected by the water level at this period. The 40 PAWD level surpassed the 60 PAWD in the accumulation of calcium, copper and manganese. In samples taken on September 9 (Table 7) calcium, copper and manganese were affected in a similar manner as before. This time nutrients which were not affected before by water application turned out to be positively affected (significant differences). The mean accumulation for nitrogen, phosphorus and magnesium was higher at the 20 PAWD. In the case of nitrogen, the 40 PAWD accumulated more than the 60 PAWD, but the difference was not significant. Manganese uptake tended to be higher at the 20 percent available water depletion level.

Seeds. There was much more nitrogen in the seeds at the 20 PAWD level than at the other two levels (Table 8). Significant interactions between the depletion levels were obtained for nitrogen (Appendix Table 27). The magnitude of the difference between the control and the various treatments narrowed down at the 60 percent available water depletion level.

Table 4. Nutrient accumulation (kg/ha) in leaves and stems on August 10, 1971.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	118.46	120.46	110.75	121.74	122.19	122.17	110.25
Phosphorus	7.67	9.17	8.34	8.76	8.36	8.21	8.26
Potassium	66.94	73.30	69.04	69.64	66.82	72.19	70.38
Calcium	36.83	39.99	36.93	41.27	35.54	39.09	35.78
Magnesium	10.87	10.45	9.90	11.05	9.85	10.57	10.14
Zinc	0.099	0.093	0.090	0.099	0.082	0.105	0.091
Copper	0.029	0.025	0.029	0.029	0.026	0.028	0.027
Iron[1]	0.703	0.595	0.569	0.667	0.530	0.647	0.647
Manganese	0.259	0.275	0.244	0.279	0.249	0.279	0.230

[1] Comparison of two depletion level means $LSD_{.05} = 0.10$

Table 5. Nutrient accumulation (kg/ha) in leaves and stems on September 6, 1971.

Element	PAWD 20	PAWD 40	PAWD 60	Stages of Water Application: Control	Vegetative	Flowering	Podding
Nitrogen	38.17	29.93	26.44	30.10	32.48	30.78	32.69
Phosphorus	3.46	2.50	2.32	2.84	2.76	2.50	2.93
Potassium	30.58	24.66	25.15	27.56	27.81	24.22	27.59
Calcium	14.79	10.51	9.87	11.22	12.12	10.83	12.73
Magnesium	6.85	5.50	4.85	5.51	5.84	5.32	6.26
Zinc	0.112	0.091	0.087	0.094	0.099	0.089	0.105
Copper[1]	0.026	0.018	0.017	0.019	0.021	0.019	0.022
Iron	0.319	0.298	0.253	0.260	0.316	0.268	0.315
Manganese	0.180	0.145	0.133	0.146	0.167	0.150	0.148

[1] Comparison of two depletion level means $LSD_{.05} = 0.007$

Table 6. Nutrient accumulation (kg/ha) in pods on August 10, 1971.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	55.17	55.43	47.83	54.75	50.71	55.55	50.23
Phosphorus	4.88	5.31	4.32	5.05	4.74	5.09	4.47
Potassium	29.02	32.11	23.61	30.10	26.77	29.77	26.36
Calcium[1]	13.29	9.66	7.59	10.82	9.12	10.21	10.56
Magnesium	2.61	2.60	2.12	2.51	2.37	2.53	2.36
Zinc[2]	0.020	0.011	0.008	0.014	0.012	0.012	0.014
Copper[3]	0.009	0.006	0.003	0.006	0.006	0.006	0.006
Iron[4]	0.209	0.204	0.129	0.187	0.186	0.172	0.176
Manganese[5]	0.065	0.047	0.031	0.052	0.041	0.048	0.051

	$LSD_{.05}$
[1] Comparison of two depletion level means	4.21
[2] Comparison of two depletion level means	0.004
[3] Comparison of two depletion level means	0.003
[4] Comparison of two depletion level means	0.06
[5] Comparison of two depletion level means	0.02

Table 7. Nutrient accumulation (kg/ha) in pods on September 6, 1971.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	199.24	126.40	112.05	118.76	158.08	149.03	157.70
Phosphorus[2]	14.51	10.48	9.19	9.35	12.14	11.23	12.86
Potassium	72.21	51.51	47.70	46.35	60.10	59.69	62.46
Calcium[3]	12.06	7.22	6.72	7.00	9.64	8.62	9.43
Magnesium[4]	8.96	5.44	4.82	5.18	6.78	6.46	7.19
Zinc	0.129	0.098	0.087	0.087	0.112	0.107	0.113
Copper[5]	0.047	0.023	0.020	0.025	0.031	0.032	0.035
Iron	0.481	0.221	0.274	0.227	0.326	0.309	0.438
Manganese[6]	0.188	0.127	0.101	0.106	0.150	0.145	0.155

	$LSD_{.05}$
[1] Comparison of two depletion level means	45.38
[2] Comparison of two depletion level means	4.13
[3] Comparison of two depletion level means	3.16
[4] Comparison of two depletion level means	1.95
[5] Comparison of two depletion level means	0.01
[6] Comparison of two depletion level means	0.04

Table 8. Nutrient accumulation (kg/ha) in seeds. 1971.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	148.24	119.11	128.34	103.62	148.45	134.19	141.31
Phosphorus[2]	12.00	9.00	9.92	7.86	11.85	10.48	10.98
Potassium[3]	35.78	28.45	30.99	24.70	35.57	32.71	33.97
Calcium[4]	2.52	2.06	2.20	1.77	2.46	2.28	2.52
Magnesium[5]	3.84	2.77	3.06	2.40	3.64	3.28	3.58
Zinc[6]	0.092	0.077	0.083	0.068	0.094	0.086	0.088
Copper	0.017	0.013	0.016	0.013	0.017	0.015	0.016
Iron	0.151	0.123	0.140	0.104	0.156	0.142	0.149
Manganese[7]	0.091	0.071	0.079	0.066	0.091	0.080	0.085

	$LSD_{.05}$
[1] Comparison of two depletion means	14.46
[2] Comparison of two depletion means	1.15
[3] Comparison of two depletion means	3.78
[4] Comparison of two depletion means	0.25
[5] Comparison of two depletion means	0.41
[6] Comparison of two depletion means	0.008
[7] Comparison of two depletion means	0.013

The greatest amount of phosphorus was accumulated at the 20 PAWD level (Table 8).

Potassium accumulation was similar to that of nitrogen. Potassium accumulation was greater at the 20 PAWD than at the 40 PAWD but not greater than at the 60 PAWD level. All depletion by stage interactions were significant (Appendix Table 27). The control plants absorbed less potassium compared to the plants that received water. The mean difference within stages (time of water application) declined at the 60 percent available water depletion level. That is, the difference in accumulation between any treated plot and the control was at its lowest at the 60 percent depletion level.

Calcium accumulation in seeds was similar to the other elements previously discussed. Relatively small amounts of calcium were taken up by the control plot. The tendency of calcium accumulation seems to favor irrigation during the period of pod-fill, but the difference was not statistically significant.

Magnesium accumulation (Table 8) was higher at the 20 PAWD and lower at the 40 PAWD level. Water application after 20 percent of the available water was depleted increased magnesium accumulation. Period of irrigation did not significantly affect the quantity of magnesium accumulated.

The pattern of uptake and accumulation of the trace elements was surprisingly similar to that of the macro-elements under investigation. Uptake of the minor elements (Table 8) increased at the 20 PAWD level more than at the other levels. Moreover, irrigation early in the growing season resulted in increased accumulation of these nutrients, but the differences were not significant. The check plots were low in the amounts of micro-nutrients absorbed and eventually translocated to the seeds.

In 1972, although the general pattern of nutrient accumulation was similar to that of 1971, irrigation had a variable effect on the accumulation of some elements. There is a slight variation in the effect of time of water application on nutrient uptake. The total dry matter and nutrient accumulation pattern is shown in Tables 9, 10, and 11.

Leaves. The application of water had a significant effect on the uptake of nitrogen, phosphorus, potassium, calcium, magnesium, and zinc (Tables 12, 13, and 14). The effect of irrigation on each of the elements mentioned was not the same at all the three sampling dates. Samples taken in July (Table 12) indicate that 20 PAWD level was favorable for nitrogen, phosphorus, potassium, calcium, magnesium and zinc uptakes. These elements constitute all the elements that were statistically analyzed. Irrigation from the start of blooming resulted in tissues with more nitrogen, phosphorus, potassium and calcium than the other treatments. Potassium, magnesium and zinc accumulations were not affected by the time at which water was applied.

The data from samples taken on August 14 (Table 13) were similar to that of the July 17 sampling date. Water application during floral development increased the accumulation of nitrogen, potassium and magnesium. More potassium and magnesium accumulated in plants irrigated at the 80 percent available moisture reserve. The results of the analysis of samples taken on September 9 (Table 14) were slightly different from that of the previous dates. Only phosphorus, potassium and zinc were significantly affected by the added water. Samples taken from plots irrigated during blooming accumulated proportionately more phosphorus than the other treatments. Plots irrigated early in the growing season and the control plots were inferior in the amounts of potassium accumulated. The 60 PAWD level appeared to be conducive for zinc accumulation in leaves.

Table 9. Total dry matter and nutrient accumulation (kg/ha) in above ground parts on July 17, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	202.79	150.64	132.69	135.59	159.99	190.25	165.31
Phosphorus	6.93	5.36	5.21	5.02	5.64	6.52	6.15
Potassium	110.72	82.36	93.40	83.08	94.25	106.91	97.72
Calcium	69.22	55.55	51.46	52.27	55.87	66.39	60.44
Magnesium	21.64	17.44	17.48	16.84	18.51	21.05	19.02
Zinc	0.220	0.145	0.148	0.155	0.156	0.192	0.181
Dry matter	6090	4790	4690	4630	4950	5800	5380

Table 10. Total dry matter and nutrient accumulation (kg/ha) in above ground parts on August 14, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	282.33	262.90	285.99	258.13	265.69	321.97	187.78
Phosphorus	12.50	10.67	10.76	10.51	10.95	12.73	11.04
Potassium	191.97	170.84	173.91	168.39	177.05	208.69	169.54
Calcium	73.60	68.79	77.56	66.14	70.95	82.65	73.42
Magnesium	31.06	27.56	28.86	26.67	27.93	33.25	28.80
Zinc	0.256	0.228	0.251	0.244	0.226	0.264	0.239
Dry matter	10430	9520	9920	9220	9520	11530	9540

Table 11. Total dry matter and nutrient accumulation (kg/ha) in above ground parts on September 9, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	355.18	384.66	421.91	351.27	343.24	454.53	399.98
Phosphorus	13.18	13.56	13.82	12.31	13.01	15.73	13.06
Potassium	199.29	209.61	230.71	206.79	206.87	236.68	202.50
Calcium	80.48	77.93	88.16	78.30	77.07	84.83	88.52
Magnesium	33.47	33.56	36.50	34.17	31.44	36.69	35.83
Zinc	0.253	0.251	0.272	0.258	0.250	0.286	0.248
Dry matter	11850	12620	13410	12060	11960	14200	12280

Table 12. Accumulation of nutrients in leaves (kg/ha) on July 17, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	145.3	108.81	92.10	97.05	113.35	138.38	115.80
Phosphorus[2]	4.40	3.32	3.03	3.03	3.35	4.17	3.78
Potassium[3]	36.55	25.39	25.42	25.20	27.72	33.05	30.50
Calcium[4]	46.22	34.40	28.58	30.28	35.03	42.84	37.45
Magnesium[5]	12.38	9.14	8.50	8.50	9.83	11.59	10.11
Zinc[6]	0.140	0.096	0.094	0.099	0.099	0.125	0.117

		$LSD_{.05}$
1	Comparison of two depletion level means	19.53
	Comparison of two stage means	22.54
2	Comparison of two depletion level means	0.63
	Comparison of two stage means	0.79
3	Comparison of two depletion level means	4.28
4	Comparison of two depletion level means	5.39
	Comparison of two stage means	7.84
5	Comparison of two depletion level means	1.35
6	Comparison of two depletion level means	0.02

Table 13. Accumulation of nutrients in leaves (kg/ha) on August 14, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	139.8	129.76	135.34	120.85	133.80	163.13	122.13
Phosphorus[2]	4.21	3.59	3.25	3.30	3.62	4.41	3.39
Potassium[3]	42.71	34.51	33.35	31.65	36.40	45.39	34.00
Calcium	36.13	33.73	35.97	32.57	34.0	39.04	35.40
Magnesium[4]	9.90	8.09	7.75	7.78	8.40	10.02	8.12
Zinc	0.134	0.117	0.119	0.129	0.115	0.133	0.117

	$LSD_{.05}$
[1] Comparison of two stage means	17.49
[2] Comparison of two depletion level means	0.97
[3] Comparison of two stage means	23.06
[4] Comparison of two stage means	3.35

Table 14. Accumulation of nutrients in leaves (kg/ha) on September 9, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	55.56	55.60	68.14	49.78	58.17	65.38	65.74
Phosphorus[1]	1.32	1.39	1.40	1.06	1.32	1.79	1.33
Potassium[2]	21.18	23.66	25.24	19.46	22.86	27.43	23.70
Calcium	34.69	37.07	41.68	33.90	36.35	39.89	41.10
Magnesium	4.34	4.55	5.16	4.40	4.13	5.03	5.18
Zinc[3]	0.051	0.047	0.061	0.049	0.054	0.062	0.057

	$LSD_{.05}$
[1] Comparison of two stage means	0.161
[2] Comparison of two stage means	3.84
[3] Comparison of two depletion level means	0.006
Comparison of two stage means	0.013

Stems. Significant differences between mean accumulations of nitrogen, potassium and zinc in stems were observed in samples taken on July 17 (Table 15). The accumulation of the above mentioned elements was greatest at the 20 PAWD level. The outcome of the next group of samples was similar, except that two additional significant cases appeared (Table 16). Nitrogen, potassium, magnesium, and zinc accumulation were influenced by the time of water application. In all instances, plants irrigated starting from time of flower formation took up more of these nutrients than the corresponding plants that were irrigated starting from the time of pod development or the control plots. Time of water application did not influence the pattern of phosphorus accumulation. The highest accumulation of phosphorus in stems was observed at the 20 PAWD level.

The results of the analysis of the samples taken on September 9 (Table 17) showed that stems accumulated more potassium when irrigation water was applied after 20 percent of the available soil moisture was used. Likewise, water application during the development of flowers increased the uptake and eventual accumulation of phosphorus in stems.

Pods (including seeds). More magnesium accumulated in pods harvested from the 60 percent available water depletion level and the lowest accumulation of these nutrients was at the 20 PAWD level (sampled August 14, Table 18). This was the reverse of what was observed for nutrient accumulation in the vegetative organs, in which case the 20 PAWD level was consistantly higher in nutrient accumulation.

In pods sampled on September 9 (Table 19) more potassium accumulated at the 60 PAWD level. The highest potassium accumulation was obtained from the 60 PAWD and the least from the 20 PAWD level. Irrigation at the time of flowering increased nitrogen accumulation. The least amount of nitrogen

Table 15. Accumulation of nutrients in stems (kg/ha) on July 17, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	57.49	41.83	40.59	38.54	46.64	51.87	49.51
Phosphorus	2.53	2.04	2.18	1.99	2.29	2.35	2.37
Potassium[2]	74.17	56.97	67.98	57.88	66.53	73.86	67.22
Calcium	23.00	21.15	22.88	21.99	20.84	23.55	22.99
Magnesium	9.26	8.30	8.98	8.34	8.68	9.46	8.91
Zinc[3]	0.080	0.049	0.054	0.056	0.057	0.067	0.064

	$LSD_{.05}$
[1] Comparison of two depletion level means	7.55
[2] Comparison of two depletion level means	7.89
[3] Comparison of two depletion level means	0.02

Table 16. Accumulation of nutrients in stems (kg/ha) on August 14, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	79.83	68.66	80.76	71.86	77.05	91.10	65.65
Phosphorus[2]	5.69	4.24	4.53	4.36	4.96	5.47	4.50
Potassium[3]	118.91	101.02	99.3	92.15	109.75	126.48	97.30
Calcium	30.68	28.87	35.07	27.41	31.38	36.89	30.48
Magnesium[4]	17.31	15.07	16.48	14.24	16.13	19.01	15.77
Zinc	0.062	0.047	0.060	0.053	0.055	0.066	0.052

	$LSD_{.05}$
1 Comparison of two stage means	17.49
2 Comparison of two stage means	0.97
3 Comparison of two depletion level means	23.06
4 Comparison of two stage means	3.35

Table 17. Accumulation of nutrients in stems (kg/ha) on September 9, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen	42.14	37.82	41.74	33.92	41.47	45.81	41.08
Phosphorus[1]	2.64	2.45	2.36	1.90	2.80	2.96	2.28
Potassium[2]	64.35	46.42	57.09	54.15	64.52	57.77	47.38
Calcium	31.24	24.44	27.65	29.36	26.25	27.07	28.42
Magnesium	13.93	11.57	12.43	13.29	11.70	12.82	12.77
Zinc	0.023	0.025	0.029	0.026	0.027	0.026	0.024

	$LSD_{.05}$
[1] Comparison of two stage means	0.76
[2] Comparison of two depletion level means	11.79

Table 18. Accumulation of nutrients in pods and seeds (kg/ha) on August 14, 1972.

Element	PAWD			Stages of Water Application			
	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	62.70	64.48	69.89	65.42	54.84	67.74	74.76
Phosphorus	2.60	2.84	2.98	2.85	2.37	2.85	3.15
Potassium	30.35	35.31	41.26	36.59	30.90	36.82	38.24
Calcium	6.79	6.19	6.52	6.16	5.57	6.72	7.54
Magnesium[2]	3.85	4.40	4.63	4.65	3.40	4.22	4.91
Zinc	0.060	0.064	0.066	0.062	0.056	0.065	0.070

	$LSD_{.05}$
[1] Comparison of two depletion level means	6.34
[2] Comparison of two depletion level means	0.49

Table 19. Accumulation of nutrients in pods and seeds (kg/ha) on September 9, 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	257.48	291.24	312.03	267.57	243.60	343.34	293.16
Phosphorus	9.22	9.72	10.06	9.35	8.89	10.98	9.45
Potassium[2]	113.76	139.53	148.38	133.18	119.49	151.48	131.42
Calcium	14.55	16.42	18.83	15.04	14.47	17.87	19.00
Magnesium	15.20	17.44	19.04	16.48	15.61	18.84	17.88
Zinc	0.177	0.179	0.182	0.183	0.169	0.198	0.167

	$LSD_{.05}$
[1] Comparison of two stages means	62.08
[2] Comparison of two depletion level means	27.05

accumulated in plots irrigated early in the ontogeny of the plants. Although the difference between the means was not significant in all cases, the 60 PAWD level was favorable for nutrient accumulation in pods.

Seeds. Table 20 shows the pattern of nutrient accumulation in mature seeds. The control plants contained the least amount of nitrogen as compared to other treatments. With the exception of calcium, the amount of nutrients accumulated in the seeds was more than that measured for the leaves or stems. The behavior of phosphorus in seeds was slightly different from its behavior in stems, leaves and pods. Irrigation during the vegetative stage increased the level of phosphorus accumulated in seeds. This level of phosphorus was significantly greater than that obtained from the control plants and that obtained by irrigating during flowering.

There were no significant differences in potassium accumulation among the three depletion levels, but the irrigated plants were superior to the control plants in the amount of potassium accumulated. The highest amount of potassium accumulation took place in plants irrigated during podding. Less magnesium was taken up by the control plants. The highest accumulation of magnesium occurred in plants irrigated from the period of pod formation. The amount accumulated at this period was significantly greater than that accumulated by irrigating after the appearance of flowers. The pattern of zinc accumulation was somewhat similar to that of magnesium. Irrigation early in the season, at and after the time of pod formation increased zinc accumulation in seeds. The magnitude of zinc accumulated from irrigation after podding was significantly greater than that accumulated by irrigation during flowering.

Table 21 shows the total water applied and yield produced in 1971 and 1972. Although the total yield in 1971 was lower than that of 1972, the

Table 20. Nutrient accumulation in seeds (kg/ha) in 1972.

	PAWD			Stages of Water Application			
Element	20	40	60	Control	Vegetative	Flowering	Podding
Nitrogen[1]	200.01	201.19	215.33	171.10	216.22	211.79	222.93
Phosphorus[2]	9.37	9.13	8.25	7.47	9.90	8.28	9.86
Potassium[3]	41.04	35.80	35.94	32.91	39.86	37.24	40.36
Calcium[4]	3.76	3.61	4.32	3.26	4.37	3.80	4.15
Magnesium[5]	5.04	4.62	4.44	4.04	4.99	4.60	5.17
Zinc[6]	0.116	0.093	0.095	0.088	0.100	0.090	0.107

	$LSD_{.05}$
[1] Comparison of two stage means	18.52
[2] Comparison of two stage means	1.24
[3] Comparison of two stage means	3.80
[4] Comparison of two stage means	0.42
[5] Comparison of two stage means	0.51
[6] Comparison of two stage means	0.01

Table 21. Total amount of water (cm) applied and seed yield (kg/ha) in 1971-72.

	1971					
	20 PAWD		40 PAWD		60 PAWD	
Stages	Water applied	Yield	Water applied	Yield	Water applied	Yield
Vegetative	36.74	3300	21.97	2742	13.98	2670
Flowering	26.22	3208	13.96	2558	12.52	2155
Podding	20.87	3359	16.37	2363	14.49	2746
	1972					
Vegetative	55.79	3689	49.57	3482	30.69	3703
Flowering	52.57	3515	45.10	3254	31.63	3831
Podding	35.00	3792	34.80	3746	30.59	3689

yield obtained for each cm of water applied (Figure 4) was higher in 1971 than in 1972 (Figure 5). In both seasons at the 20 PAWD level, the yield per cm of water applied during the stage of pod-fill was about double the amount for irrigating early in the growing season. At the 40 PAWD level this value was higher for irrigation during podding and lower for early irrigation. At the highest level of depletion (60), it did not make any difference whether water was applied during vegetative, flowering or pod-filling stage. The total amount of yield produced by irrigating during pod development was greater than that obtained by irrigating during vegetative or flowering stage.

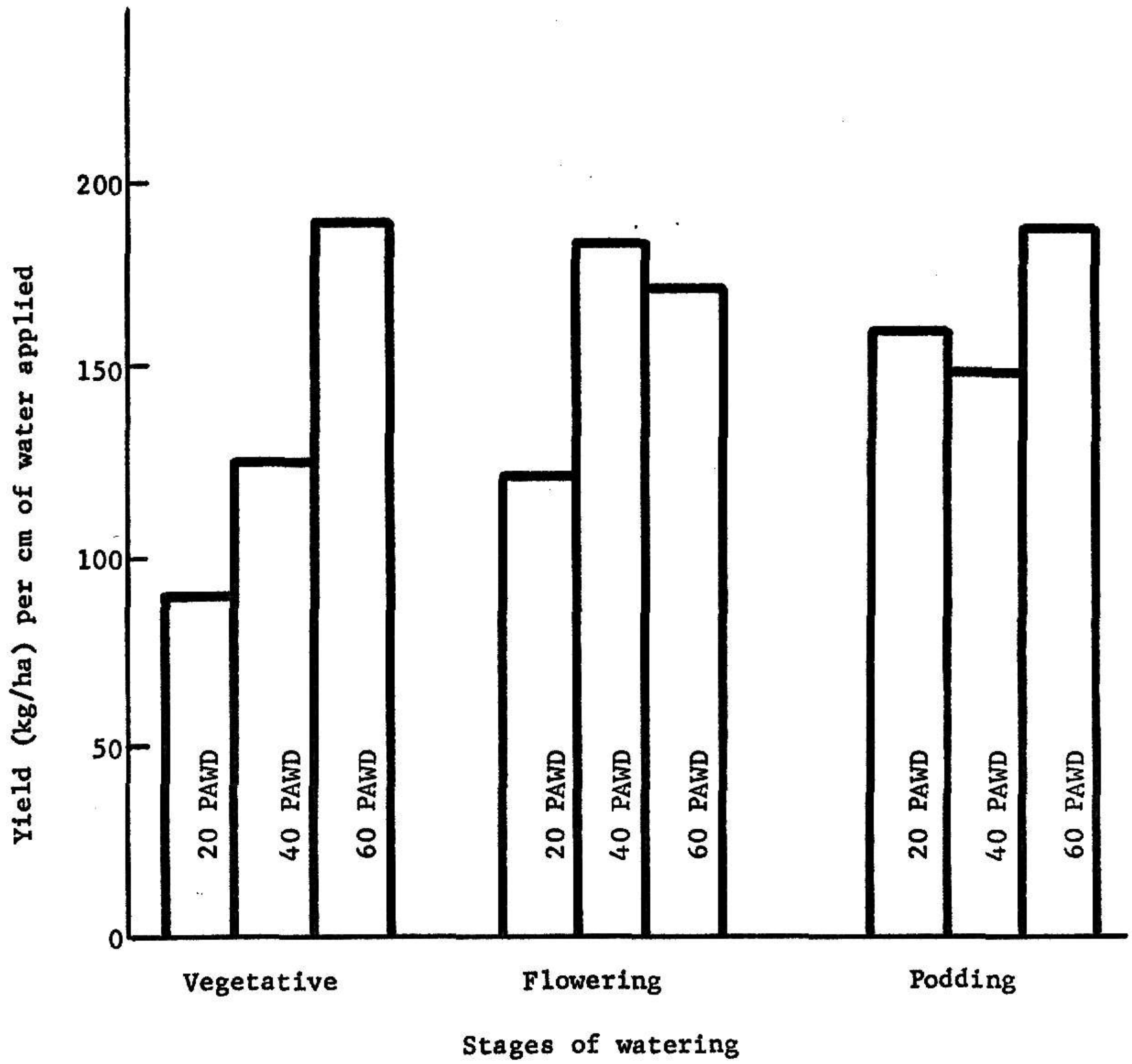

Figure 4. Seed yield (kg/ha) per cm of water applied at different available water depletion levels and stages of watering (1971).

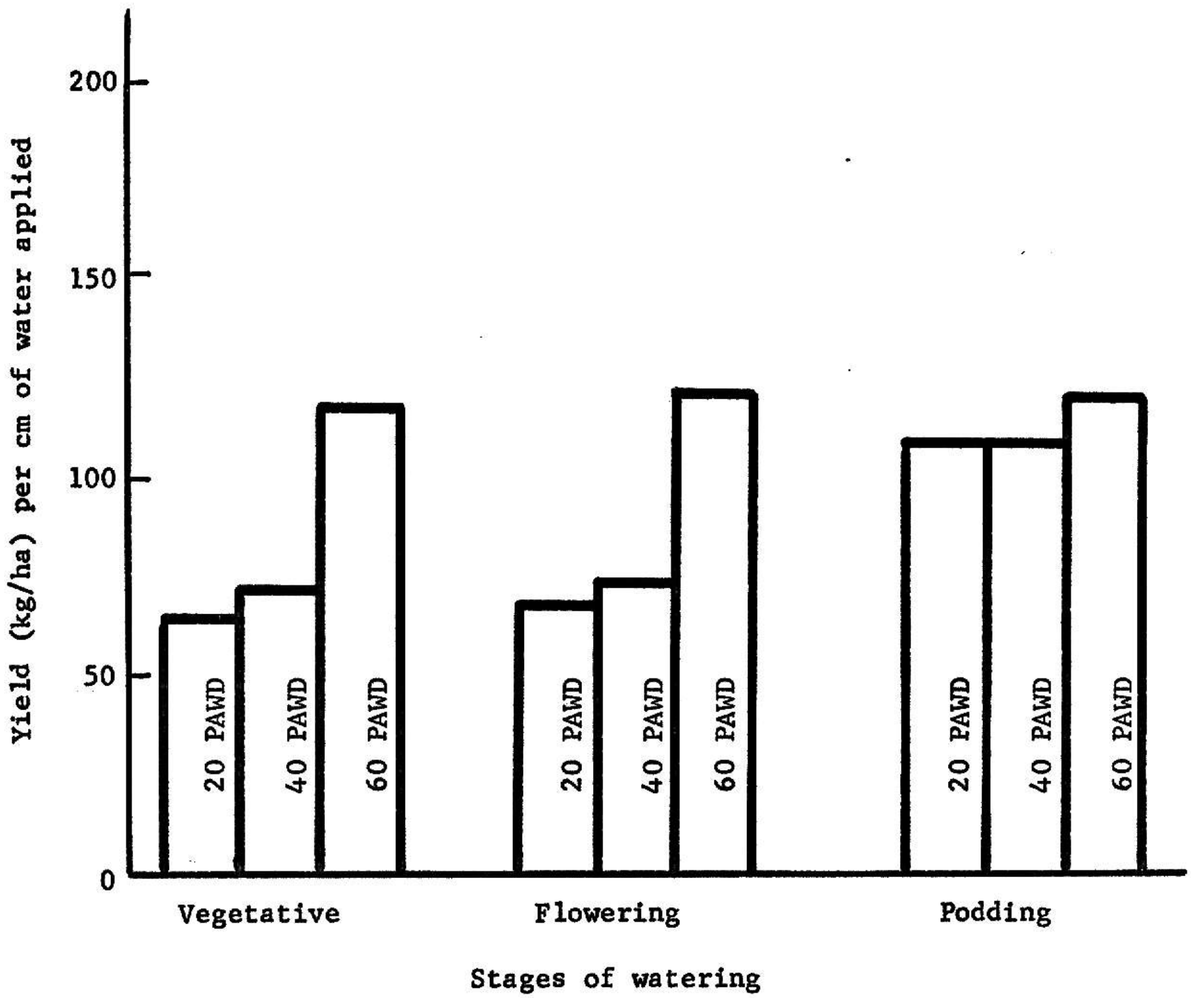

Figure 5. Seed yield (kg/ha) per cm of water applied at different depletion levels and stages of watering (1972).

DISCUSSION

The pattern of dry matter accumulation (Table 1) was similar to that obtained by Hanway and Weber (1971). After peak accumulation the dry matter in leaves and stems declined and was accompanied by a concomitant increase of dry matter in pods and seeds. It reflects the redistribution of dry matter from old tissues to actively developing pods and eventually to the seeds.

The difference in magnitude of dry matter accumulation between the two years (Figure 1) was due to the interaction between the genotype and the environment. More precipitation was received in 1972 than in 1971. Also more water was applied in 1972 than in 1971.

Application of water did not have a significant effect on the dry matter accumulation in the vegetative parts in 1971 (Table 1). Upon separation of the vegetative parts into stems and leaves in 1972 (Appendix Table 26) significant differences were obtained in the dry weight of leaves. This indicates that the variation of moisture within the plant had more effect on the dry weight of leaves than that of stems.

The characteristically high yield at the 20 PAWD level and low yield at the 40 PAWD and 60 PAWD in 1971 (Table 2) levels indicates that yield was related to the amount of moisture supply. In 1972 the highest yield was obtained when water was applied during the period of pod development. Norman (1963) emphasized that from the standpoint of yield and moisture requirement, the pod-filling stage is the most critical. This result and various other experiments (Ohlrogge, 1968) suggest that the soybean plant is sensitive to a shortage of water from the time of flowering until the end of fruiting.

Since water application has resulted in yields only slightly higher than that obtained from the control plot, would it pay to irrigate soybeans when actual precipitation is not deficient is a question that should be given serious consideration.

The lodging score was higher at the 20 PAWD level and for the plots that received water during the vegetative stage. This indicated that there was a direct relationship between lodging and the amount and number of times water was applied to the plots.

Accumulation of nitrogen, phosphorus and potassium (Tables 3-7) agrees with the works of Hanway and Weber (1971) and Henderson and Kanprath (1970). At about the time of pod-fill the amount of nutrient accumulation in the vegetative parts dropped. The decline in nutrient content of stems and leaves as the season progressed was due to the redistribution or transfer of nitrogen, phosphorus and potassium from old tissue to the actively growing part of the plant or the seed.

Like the total dry matter, the amount of nutrient accumulated within the plant in 1971 was less than that of 1972 (Tables 3 and 9). This condition was related to the amount of precipitation for the two years. The phenomenon of more nitrogen accumulation under abundant moisture (20 PAWD) (Tables 8, 12, 13, 15, and 17) is in contrast to the established fact that decreases in soil moisture supply are associated with a substantial increase in the uptake of nitrogen. According to Friedman (1967) this is true only if growth is limited by soil moisture.

In 1972 irrigation during floral development and pod-filling stages increased nitrogen accumulation within the plant (Tables 9, 10, and 11).

The 20 PAWD level resulted in increased phosphorus uptake by the plants. Irrigation during flowering and pod-filling stages significantly increased the phosphate content within the plants. The effect of irrigation on phosphorus uptake was not consistent. Such inconsistent effect of soil moisture on phosphorus nutrition was reported by Mann and Jaworski (1970).

Potassium accumulation was similar to that of nitrogen. In both seasons the highest accumulation of potassium in seeds and pods occurred at the 20 PAWD level.

Calcium accumulation was higher at the 20 PAWD level (Table 12). Irrigation during flowering and podding increased calcium accumulation in seeds. But variable results were obtained for leaves, stems and pods in 1971 (Tables 3, 4 and 5). At times the control plants accumulated more calcium than the irrigated plants (Tables 4 and 6). It is repeatedly reported that soil moisture has virtually no effect on calcium content of plants (Russell, 1962). Mature seeds contained less calcium than the vegetative parts at all the levels of water depletion and at all the stages at which water was applied. This shows that there was little or no redistribution of calcium from the vegetative part to the seeds.

Higher magnesium accumulation took place in plants that received water during podding and flowering. There was no significant difference in the amount accumulated between these two stages.

The pattern of accumulation of the minor elements was similar to that of the major elements (Tables 3, 4, 5 and 6). The total amount of zinc accumulation was high where irrigation water was applied during flowering or during podding. Copper, iron, and manganese accumulations did not vary significantly with time of application.

The low uptake of micro-elements (except manganese) by plants irrigated during the vegetative stage signified that continued irrigation was not necessary for the accumulation of the trace elements.

The computations of the amount of yield produced for each cm of water applied (Table 22) indicate that irrigation when 80 percent of the available water was still present within the root domain, was not efficient. The yield for each cm of water applied was low for early irrigations as compared to irrigations during flowering or pod development. This is possible, for at the 20 PAWD level the increase of yield might have been compensated for by the decreases caused by lodging.

If water has to be applied at the 20 PAWD level, depending upon the supply, it should be applied during podding stage of the growth and development of the plant. If yield is the only criterion of concern, water could be applied at any stage to maintain 60 PAWD.

In the relatively dry season (1971), since nutrient accumulation in the seeds was greater at the 20 PAWD level than the other two levels, it would seem appropriate to consider irrigation during the period of pod development whenever the available soil moisture supply falls below the 80 percent level. On the other hand, in seasons when the natural precipitation is not limiting (1972), irrigation water could be utilized more efficiently by applying at the 60 PAWD level during the period of pod and seed development.

Table 22. Seed yield (kg/ha) per cm of water applied.

PAWD	Vegetative	Flowering	Podding
		1971	
	Stages of Water Application		
20	89.8	122.3	160.9
40	124.8	183.2	147.7
60	191.0	172.1	189.5
		1972	
20	66.1	66.9	108.3
40	70.2	72.2	107.6
60	120.7	121.1	120.6

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APPENDIX

Table 23. Time and amount of water applied, 1971.

Date of application	Percent available water depletion	Stages of development	Amounts applied in cm
June 25	20	Vegetative	9.26
June 28	60	Vegetative	7.46
June 29	40	Vegetative	8.22
July 19	20	Vegetative	7.81
July 19	20	Flowering	7.29
August 3	20	Podding	6.14
August 3	40	Podding	6.48
August 3	60	Podding	5.93
August 10	20	Vegetative	7.77
August 10	20	Flowering	6.98
August 13	40	Vegetative	7.23
August 13	40	Flowering	7.44
August 18	20	Podding	9.02
August 20	20	Vegetative	6.03
August 20	20	Flowering	6.08
August 27	20	Podding	5.71
August 27	40	Podding	9.89
August 27	60	Podding	8.56
September 2	20	Vegetative	5.87
September 2	20	Flowering	5.87
September 2	40	Vegetative	6.52
September 2	40	Flowering	6.52
September 2	60	Vegetative	6.52
September 2	60	Flowering	6.52

Table 24. Time and amount of water applied, 1972.

Date of application	Percent available water depletion	Stages of development	Amounts applied in cm
June 28	20	Vegetative	8.15
June 28	40	Vegetative	6.88
July 5	20	Vegetative	6.96
July 5	20	Flowering	10.72
July 5	40	Vegetative	6.50
July 5	40	Flowering	9.30
July 5	60	Vegetative	6.50
July 5	60	Flowering	8.13
July 14	20	Vegetative	6.02
July 14	20	Flowering	6.48
July 14	40	Vegetative	6.05
July 14	40	Flowering	6.10
July 25	20	Vegetative	4.70
July 25	20	Flowering	5.05
August 2	20	Vegetative	6.38
August 2	20	Flowering	6.53
August 2	20	Podding	7.37
August 2	40	Vegetative	6.38
August 2	40	Flowering	6.45
August 2	40	Podding	7.57
August 7	20	Podding	2.21
August 7	40	Podding	2.26
August 7	60	Vegetative	6.05
August 7	60	Flowering	6.05
August 7	60	Podding	6.17
August 8	60	Vegetative	9.40
August 8	60	Flowering	9.37
August 8	60	Podding	9.63
August 9	20	Vegetative	5.72
August 9	20	Flowering	5.72
August 9	40	Vegetative	5.72
August 9	40	Flowering	5.72
August 11	20	Podding	6.93
August 11	40	Podding	6.76
August 15	20	Vegetative	7.09
August 15	20	Flowering	7.09
August 15	20	Podding	7.59
August 15	40	Vegetative	7.19
August 15	40	Flowering	6.88
August 15	40	Podding	7.44
August 17	20	Vegetative	4.72
August 17	20	Flowering	4.93
August 17	20	Podding	4.85

Table 24. Continued.

Date of application	Percent available water depletion	Stages of development	Amounts applied in cm
August 17	40	Vegetative	4.80
August 17	40	Flowering	4.60
August 17	40	Podding	4.72
August 18	60	Vegetative	8.08
August 18	60	Flowering	8.08
August 18	60	Podding	8.08
August 21	60	Vegetative	6.71
August 21	60	Flowering	6.71
August 21	60	Podding	6.71
August 23	20	Vegetative	6.05
August 23	20	Flowering	6.05
August 23	40	Vegetative	6.05
August 23	40	Flowering	6.05
August 24	20	Podding	6.05
August 24	40	Podding	6.05

Table 25. Dry matter and nutrient accumulation (kg/ha) in the vegetative parts (sampled July 13, 1971).

Dry Matter

Stages	Depletion level 20	40	60
Control	3250	2480	2260
Vegetative	2490	2670	2940
Flowering	2200	2240	3060
Podding	2850	2850	2690

$LSD_{.05} = 168.3$

Nitrogen

Stages	Depletion level 20	40	60
Control	92.46	70.69	65.86
Vegetative	69.58	79.32	88.14
Flowering	63.96	71.22	87.67
Podding	78.69	84.97	77.95

$LSD_{.05} = 21.97$

Phosphorus

Stages	Depletion level 20	40	60
Control	7.69	6.20	5.64
Vegetative	5.92	6.99	7.22
Flowering	5.29	6.02	8.32
Podding	6.23	7.53	6.55

$LSD_{.05} = 1.96$

Table 25. Continued.

Potassium			
	Depletion level		
Stages	20	40	60
Control	66.56	44.40	48.98
Vegetative	59.75	51.00	59.70
Flowering	46.20	45.08	71.44
Podding	53.29	56.52	52.94

$LSD_{.05} = 16.71$

Calcium			
	Depletion level		
Stages	20	40	60
Control	27.75	18.47	14.40
Vegetative	20.46	20.18	20.50
Flowering	17.04	17.51	23.20
Podding	21.28	23.92	20.16

$LSD_{.05} = 7.12$

Magnesium			
	Depletion level		
Stages	20	40	60
Control	8.69	6.51	6.32
Vegetative	6.48	7.10	8.11
Flowering	5.56	6.23	8.67
Podding	6.83	8.07	7.18

$LSD_{.05} = 2.29$

Table 25. Continued.

Iron			
	Depletion level		
Stages	20	40	60
Control	0.89	0.55	0.41
Vegetative	0.42	0.42	0.50
Flowering	0.49	0.49	0.57
Podding	0.57	0.74	0.47

$LSD_{.05} = 0.13$

Manganese			
	Depletion level		
Stages	20	40	60
Control	0.162	0.112	0.108
Vegetative	0.104	0.123	0.130
Flowering	0.099	0.111	0.136
Podding	0.120	0.147	0.115

$LSD_{.05} = 0.412$

Table 26. Dry matter accumulation (kg/ha) in the vegetative parts (sampled July 17, 1972).

Leaves

Stages of watering[1]	20 PAWD[2]	40 PAWD	60 PAWD
Control	2510	1790	1530
Vegetative	2450	2160	1870
Flowering	3000	2670	2120
Podding	3370	1810	1830

[1] Comparison of two stage means $LSD_{.05} = 679.8$

[2] Comparison of two depletion level means $LSD_{.05} = 241.2$

Stems

Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	2920	2310	2820
Vegetative	2980	2800	2600
Flowering	3160	3230	3220
Podding	3960	2420	2750

Table 27. Dry matter and nutrient accumulation in seeds in 1971.

Dry matter (kg/ha)			
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	1669	1269	1966
Vegetative	2708	2232	2173
Flowering	2607	2082	1756
Podding	2626	1923	2235

$LSD_{.05} = 13.39$

Nitrogen (kg/ha)			
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	102	83	125
Vegetative	169	139	137
Flowering	160	130	112
Podding	160	124	139

$LSD_{.05} = 22.64$

Phosphorus (kg/ha)			
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	7.78	5.90	9.87
Vegetative	14.57	10.70	10.26
Flowering	12.77	9.95	8.72
Podding	12.73	9.40	10.81

$LSD_{.05} = 1.96$

Table 27. Continued.

	Potassium (kg/ha)		
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	25.04	18.44	30.63
Vegetative	39.38	33.76	33.57
Flowering	38.88	32.24	26.89
Podding	39.82	29.23	32.87

$LSD_{.05} = 6.13$

	Calcium (kg/ha)		
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	1.79	1.44	2.07
Vegetative	2.76	2.27	2.34
Flowering	2.74	2.22	1.90
Podding	2.78	2.30	2.49

$LSD_{.05} = 0.38$

	Magnesium (kg/ha)		
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	2.43	1.80	2.97
Vegetative	4.40	3.32	3.20
Flowering	4.21	3.00	2.63
Podding	4.34	2.97	3.42

$LSD_{.05} = 0.69$

Table 27. Continued.

Zinc (kg/ha)			
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	0.068	0.055	0.082
Vegetative	0.104	0.089	0.090
Flowering	0.098	0.087	0.073
Podding	0.099	0.078	0.087

$LSD_{.05} = 0.015$

Copper (kg/ha)			
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	0.015	0.010	0.015
Vegetative	0.019	0.016	0.016
Flowering	0.018	0.013	0.014
Podding	0.017	0.012	0.019

$LSD_{.05} = 0.003$

Manganese (kg/ha)			
Stages of watering	20 PAWD	40 PAWD	60 PAWD
Control	0.063	0.048	0.087
Vegetative	0.101	0.088	0.083
Flowering	0.101	0.073	0.066
Podding	0.101	0.077	0.079

$LSD_{.05} = 0.018$

THE EFFECT OF IRRIGATION ON DRY MATTER AND NUTRIENT ACCUMULATION IN SOYBEAN (GLYCINE MAX (L.) MERRILL) PLANTS

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Effects of water application on the accumulation of the dry matter and nutrient uptake were studied. Five macro-elements and four micro-elements were determined from samples taken at an interval of 15 days--starting from 15 days after emergence. In 1971, the samples taken were separated into the vegetative parts, pods and seeds. In 1972, leaves and stems were separately studied.

Water application did not significantly affect the total dry matter accumulation. The greatest accumulation of nutrients occurred at the 20 percent available water depletion level. Irrigation during and after flowering increased nutrient accumulation in the vegetative parts. The highest accumulation of nutrients in pods occurred where water was applied during the period of pod development.

In 1971, when the rainfall was relatively low, irrigation early in the development of the plant increased the amount of nutrient accumulated in the seed. On the other hand, in 1972, when the annual rainfall was relatively high, early application of water (vegetative stage) did not result in increased accumulation of nutrients in seeds.

At the 20 PAWD level water was most efficiently utilized by plants that received water during podding and least efficiently by those irrigated during the vegetative stage. At the highest level of depletion (60%) time of water application did not have a marked effect on the efficiency of the water applied.