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Effect of Phosphorus and Split Nitrogen on Corn (*Zea mays* L.) Production, Nitrogen and Phosphorus Accumulation in Western Saudi Arabia

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ABSTRACT. Field experiments were conducted during the spring and autumn of 1992 to determine the effects of phosphorus and split N application on corn total biomass (TDM and TDW) and in its components, *viz*., culm (CDW), leaves (LDW) and cobs (CBDW) accumulation of N and P. A hybrid cultivar, "Giza 2" was sown under 4 levels of N (100, 150, 300 and 400 kg ha^{-1}) split into four equal doses at 15, 30, 45 and 60 days from planting (dfp); and 2 levels of P (75 and 150 P_2O_5 kg ha^{-1}) applied at sowing. Estimates of TDM and CDW at 30 and 45 dfp (both seasons) and at 60 dfp (spring season) were highest ($P \leq 0.01$) at the N_3 level, indicating that split application of 225 kg N ha^{-1}) in the spring and of 150 kg N ha^{-1} in the autumn were adequate for achieving maximum biological and seed yields. N and P uptake in the leaves, being highest at 30 to 60 dfp, was also significantly increased by the split doses of N_3 (*i.e*. 75, 150 and 225 Kg N ha^{-1}), depending on season, at the specified harvesting dates. Positive effects of P_2 were limited to those on CDW at 30 dfp in the spring season and at 30 and 45 dfp in autumn. Effects of P_2 on CBDW and TDW at 90 dfp in the autumn season were also significant but negative. Positive effects of ($P \leq 0.05$) of P_2 on N content were only recorded for leaves at 45 dfp in the autumn; whereas those on P uptake were limited for leaves at 30 and 75 dfp in the spring season.

Introduction

Nitrogen is normally a key factor in achieving optimum cereal grain yields. Plant use efficiency of N is dependent on several factors, including application time (Abdel-Aziz *et al.*, 1986 and Badreshia and Patel, 1987); rate of N applied, source of N (Grove *et al.*, 1980; Njoku and Odurukwe, 1987; Lucas, 1986, and Soelaeman, *et al.*, 1987); cultivar (Soelaeman *et al.*, 1987) and climatic-related variable (Hane, 1981).

Maximum efficiency should be obtained by the latest possible application compatible with the stage of development that still permits rapid N uptake. Thus avoiding unnecessary vegetative growth, which may result in lodged plants and subsequent grain yield reduction. Furthermore, the opportunities for N losses by leaching are reduced, because an active root system is present for absorbing the fertilizer N when it is applied. One possible approach to reduce fertilizer N without affecting yield, is reducing preheading rates of N and top-dressing N later in the season (Purcell, 1990).

Responses to split N applications reported in literature, however, are inconsistent. Top-dressing N on wheat during the spring resulted in higher yields as compared with preplant N. No advantages in split application of N were reported by Grant *et al.* (1985).

In Saudi Arabia, corn is generally grown as a dual purpose (*i.e.* for both fodder and grain) crop in both spring and autumn and usually under high levels of N and P fertilizers. This study was therefore undertaken to determine the N and P fertility requirements for corn optimum biological yield, grain yield, N and P uptake and dry matter production.

Materials and Methods

The experiments were conducted in King Abdulaziz University, Agricultural Research Farm at Hada Al-Sham, during the spring and autumn seasons of 1992. The Soil characteristics and the meteorological data for the experimental site are presented in Tables 1 and 2. The experiment included a hybrid cultivar (Giza 2) that is well adapted in Western Saudi Arabia. Trial was laid out in a split-plot design keeping phosphorus levels in the main plots and nitrogen levels in sub-plots with four replications. The experiment had four levels of nitrogen (100, 200, 300 and 400 kgN/ha) in the form of urea and two levels of phosphorus (75 and 150 kg P_2O_5/ha) in the form of superphosphate. The crop was seeded at 75 kg/ha, keeping row to row distance of 30 cm. Crop was sown on 28 February and 28 September 1992. Prior to planting a basal dose of 75 kg K_2O ha^{-1} in addition to 75 and 150 kg P_2O_5 ha^{-1} were applied. Nitrogen was splited into four equal doses; the first of which was applied (side dressing) 15 days after emergence and the last at 60 days after emergence. Irrigation and weeding were practiced when needed.

Five adjacent plants per each treatment were sampled at 45, 60, 75 and 90 days from planting (dfp) in each season. For each sample, data were taken on culm, leaf, cob and tassel dry weights. N and P contents in various plant parts at each sampling date were also determined. Analyses of variance were performed as outlined by Little and Hill (1978).

Results and Discussion

Data in Table 3 revealed high significant differences ($P \leq 0.01$) between the spring and autumn cropping in culm, leaf and cob dry weights. Annual averages for total dry weight (TDW), being 403.9 and 404.9 g m^{-2} in the respective seasons, were statistically similar. Differences among sampling dates within each planting season were also high-

TABLE 1. Physical and chemical characteristics of the soil at the experimental site in Hada Al-Sham.

Soil texture	Major components			Characteristics and chemical constituents				
	Sand	Silt	Clay	pH	EC	N	P	K
	(%)				ds / m	kg / ha		
Sandy loam	18	10	12	8.2	0.96	0.17	0.20	2.61

TABLE 2. Meteorological data at the experimental site during the planting seasons at Hada Al-Sham.

Spring 1992					Autumn 1992				
Month	Temperature °C			R.H.	Month	Temperature °C			Mean R.H.
	Min.	Max.	Mean	(%)		Min.	Max.	Mean	(%)
February	6.3	38.4	22.2	54	September	21.3	45.2	33.1	53
March	10.0	39.1	20.2	53	October	18.5	44.2	31.1	49
April	11.4	40.3	27.7	48	November	15.8	38.5	27.0	65
May	15.0	44.7	31.2	49	December	11.8	37.3	23.6	66
June	18.2	48.7	32.4	46	January	10.2	35.9	23.8	59

TABLE 3. Effect of season and sampling date on total biomass (TDW and TDM) and its components.

Sampling date (dfp)	Dry weights (g m^{-2}) of							
	Culm		Leaves		Cobs		Total biomass	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
1st (30)	61.4	59.6	109.0	106.9	-	-	170.5	166.4
2nd (45)	90.1	81.2	98.2	137.3 ±	-	-	188.4	218.5
3rd (60)	157.7	259.6	87.4	133.7	24.8	49.6	273.8	442.5
4th (75)	272.2	232.3	164.8	142.1	28.4	379.7	465.2	754.1
5th (90)	433.4	224.5	257.4	135.4	609.5	487.9	1325.2	847.9
	± 4.1**		± 3.2**		± 11.3**		± 10.6**	
Mean ± S.E.	169.2 ± 10.6**	142.9 ± 7.3**	119.5 ± 8.5**	109.2 ± 1.7**	184.1 ± 10.8**	254.8 ± 25.4**	403.9 ± 22.1**	404.9 ± 25.3**

a: S_1 and S_2 in this Table and Table 4 indicate first (spring) and second (autumn) seasons, respectively.
* and ** indicate significant differences at 5 and 1% levels, respectively.

ly significant for each of the studied traits (Table 3). In this respect about 89% (754 mg m^{-2}) of the target (final biomass or TDW (847.9 g m^{-2}) was attained at 80 dfp in the autumn season (Table 3). At this date contributions of culm dry weight (CDW), leaf dry weight (LDW) and cob dry weight (CBDW) represented respectively 30.8, 18.8 and 50.4% of the total dry weight. In the spring season only 35.1% (465.1 g m^{-2}) of the target biomass (1325.2 g m^{-2}) were attained at 80 dfp; the contributions of CDW, LDW and CBDW in TDW were respectively 58.5, 35.4 and 61.1% (Table 3). Apparently, the relatively fast growth attained during the first two months of autumn and the last two months of spring plantings were mostly attributed to the relatively high temperatures that prevailed during these periods (Table 2). Because yields varied in relation to seasonal climatic differences and crop use, it is evident that an early harvest (*i.e.* at 45-75 dfp) for forage favours autumn planting better than spring planting. Otherwise, spring planting would be more profitable for dual purpose (hay and grain production) corn, which is in harmony with Hane (1981), who indicated that spring planting resulted in significantly higher estimates of total biomass at the final harvest as compared to autumn planting.

Data in Table 4 revealed that culm and TDW at 30, 45 and 60 dfp in the spring season an at 30 and 45 dfp in autumn were significantly influenced by N. At all dates highest ($P \leq 0.01$) amounts of CDW and TDW were attained at the N_3 level (Fig. 1). Application of P, on the other hand, significantly affected CDW at 30 dfp ($P \leq 0.01$) in the spring and at 30 dfp ($P \leq 0.01$) and 45 dfp ($P \leq 0.05$) in autumn (Table 4). At both dates, highest CDW estimates were recorded at the P_2 level (Fig. 2). At later dates (Table 4), P_2 significantly ($P \leq 0.05$) reduced CDW (Fig. 2) at 75 dfp and CBDW and TDW at 90 dfp in the second season (Fig. 2).

Interactions between N and P were also significant for CDW and TDW at 30, 45 and 60 dfp in spring and at 30 and 45 dfp in autumn (Table 4). At all dates, estimates of CDW and TDW were highest at the N_3P_2 level (data not shown).

Thus it is evident from this data that application of split doses of N, irrespective of its level, at dates later than 45 dfp (spring) and 30 dfp (autumn) had no positive effect on total biomass or its components in relatively late harvests (Fig. 1). The lack of response at the late harvests may be attributed to the prevailing temperatures (high or low) that limited the efficiency of the growing plant in utilizing the late applied nitrogen. The tendency for P_2 application to increase CDW and TDW at early plant stages (30 to 45 dfp) and decrease CDW, CBDW and/or TDW (Fig. 2) at later stages (75 to 90 dfp) is an indication that increasing levels of late released P had adverse effects on TDM and its components. Apparently, addition of 150 kg P_2O ha^{-1}, especially in autumn planting, was in excess of the actual plant needs. Similar results were reported for maize (Abdel-Aziz *et al.*, 1986; Badreshia and Patel, 1987; El-Baisary *et al.*, 1980; Kharkar, 1980; Okajima *et al.*, 1983 and Salih and Wali, 1988).

Nitrogen accumulation (all organs) and phosphorus accumulation (culms and leaves) during the growing were also significantly ($P \leq 0.01$) affected by season (Table 5). On the average, the highest estimates of N and P contents in leaves, culms and cobs were recorded within the first and third sampling dates (30-60 dfp) and lowest estimates at the 4th or 5th sampling date (Table 5), indicating a reduction in the efficiency of the corn plant in accumulating N (Fig. 3) and P (Fig. 4) as the season advanced (Fig. 3 and 4).

Effects of N application on N accumulation, on the other hand, were only significant for leaves at first and second harvest and for culms at the third harvest of the spring season (Table 4). Significant effects of N on P accumulation were recorded for leaves at the first harvest of the autumn season and at the second and third harvests of the spring season (Table 4). At all harvesting dates estimates of N (Fig. 3) and of P (Fig. 4) were

TABLE 4. Analysis of variance for culm, leaf and cob dry weights, their N and P contents and total dry matter under different levels of N and P at five sampling dates.

Sampling date (dfp)	Para-meter	d.f. (a)	Culm			Leaves			Cobs			TDM	Culm			Leaves			Cobs			TDM
			W	N	P	W	N	P	W	N	P		W	N	P	W	N	P	W	N	P	
			Significance of F-values																			
1st (30	N	3---	**	ns	ns	ns	*	ns	–	–	–	**	**	ns	ns	ns	ns	ns	–	–	–	**
	P	1---	**	ns	ns	ns	ns	*	–	–	–	ns	**	ns	ns	ns	*	ns	–	–	–	ns
	NP	3---	**	ns	ns	ns	ns	ns	–	–	–	**	**	ns	ns	ns	ns	ns	–	–	–	**
2nd (45)	N	3---	**	ns	ns	ns	*	*	–	–	–	**	**	ns	ns	ns	ns	ns	–	–	–	**
	P	1---	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
	NP	3---	**	ns	ns	ns	ns	ns	ns	ns	ns	**	**	ns	ns	ns	ns	ns	ns	ns	ns	**
3rd (60)	N	3	**	8	ns	ns	ns	*	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	P	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	NP	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
4th (75)	N	3	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	P	1	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
	NP	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
5th (90)	N	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	P	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**
	NP	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

a degrees of freedom for error at each sampling date = 24

b W, N and P stand for dry weight, nitrogen and phosphorus, respectively.

* and ** indicate significant differences at 5 and 10% levels, respectively.

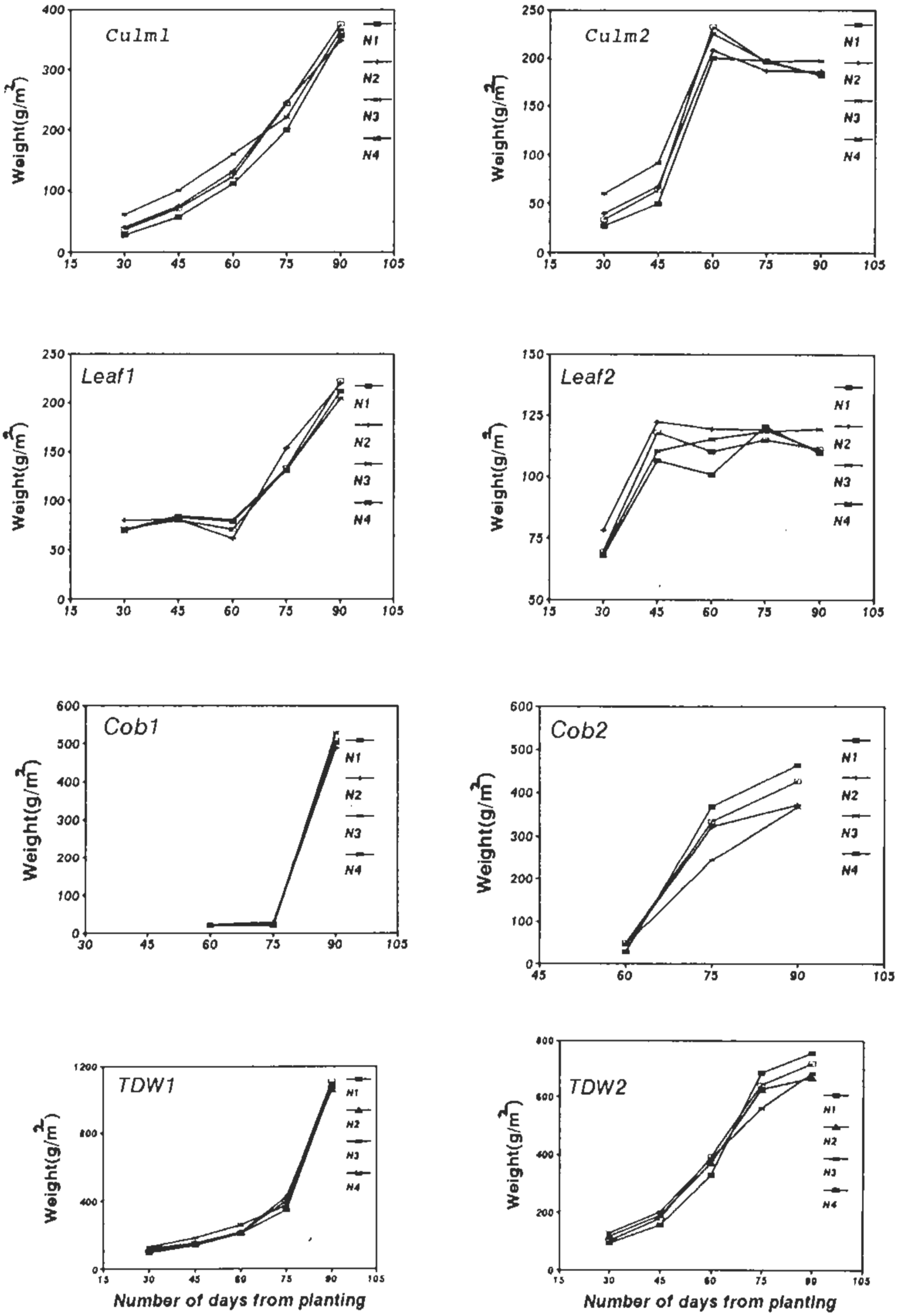

FIG. 1. Annual effect of nitrogen on total dry weight (TDW) and its components in 1st(1) and 2nd(2) seasons.

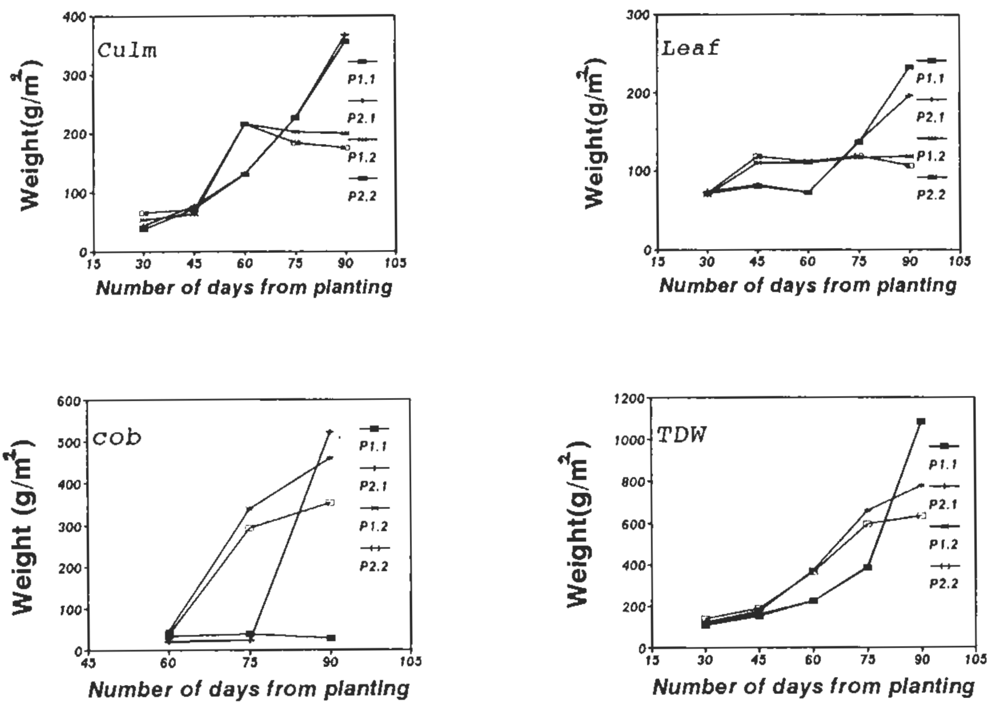

FIG. 2. Effect of phosphorus (P_1 & P_2) on the total dry weight (TDW) and its components in 1st(.1) and 2nd(.2) seasons.

TABLE 5. Effect of season and sampling date on N and P contents of culms, leaves and cobs.

Sample date (dfp)	Nitrogen content (g/kg) of						Phosphorus content (g/kg) of					
	culm		leaf		cob		culm		leaf		cob	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
1st (30)	1.926	2.100	2.200	.3.036	–	–	0.583	0.206	0.548	0.422	–	–
2nd (45)	1.470	1.438	2.382	2.456	–	–	0.407	0.245	0.589	0.367	–	–
3rd (60)	1.014	0.977	2.559	2.824	2.826	2..783	0.238	0.184	0.638	0.384	0.501	0.494
4th (75)	0.806	0.456	2.151	2.587	1.565	1.388	0.223	0.169	0.423	0.322	0.488	0.409
5th (90)	0.619	0.513	1.465	2.339	1.384	1.374	0.187	0.175	0.298	0.235	0.566	0.557
	± 0.20**		± 0.035**		± 0.019**		± 0.010**		± 0.012**		± 0.020	
Mean ± S.E.	1.167 ± 0.072**	1.097 ± 0.053**	2.151 ± 0.094**	2.648 ± 0.063**	1.925 ± 0.035**	1.848 ± 0.032	0.246 ± 0.023**	0.196 ± 0.023	0.499 ± 0.093	0.350 ± 0.024**	0.518 ± 0.036	0.487 ± 0.035**

* and ** indicate significant differences at 5 and 10% levels respectively.

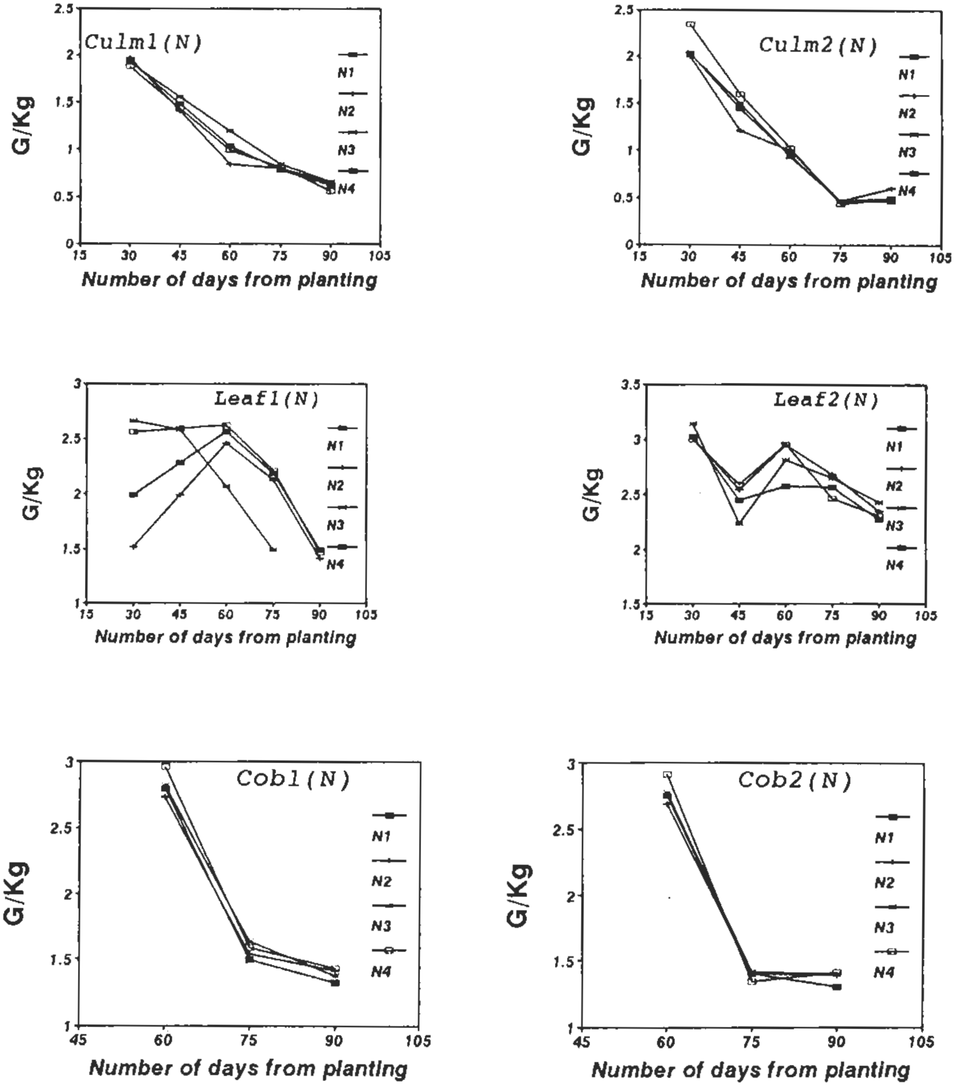

FIG. 3. Annual effect of nitrogen on nitrogen content of culm, leaves and cobs in 1st(1) and 2nd(2) seasons.

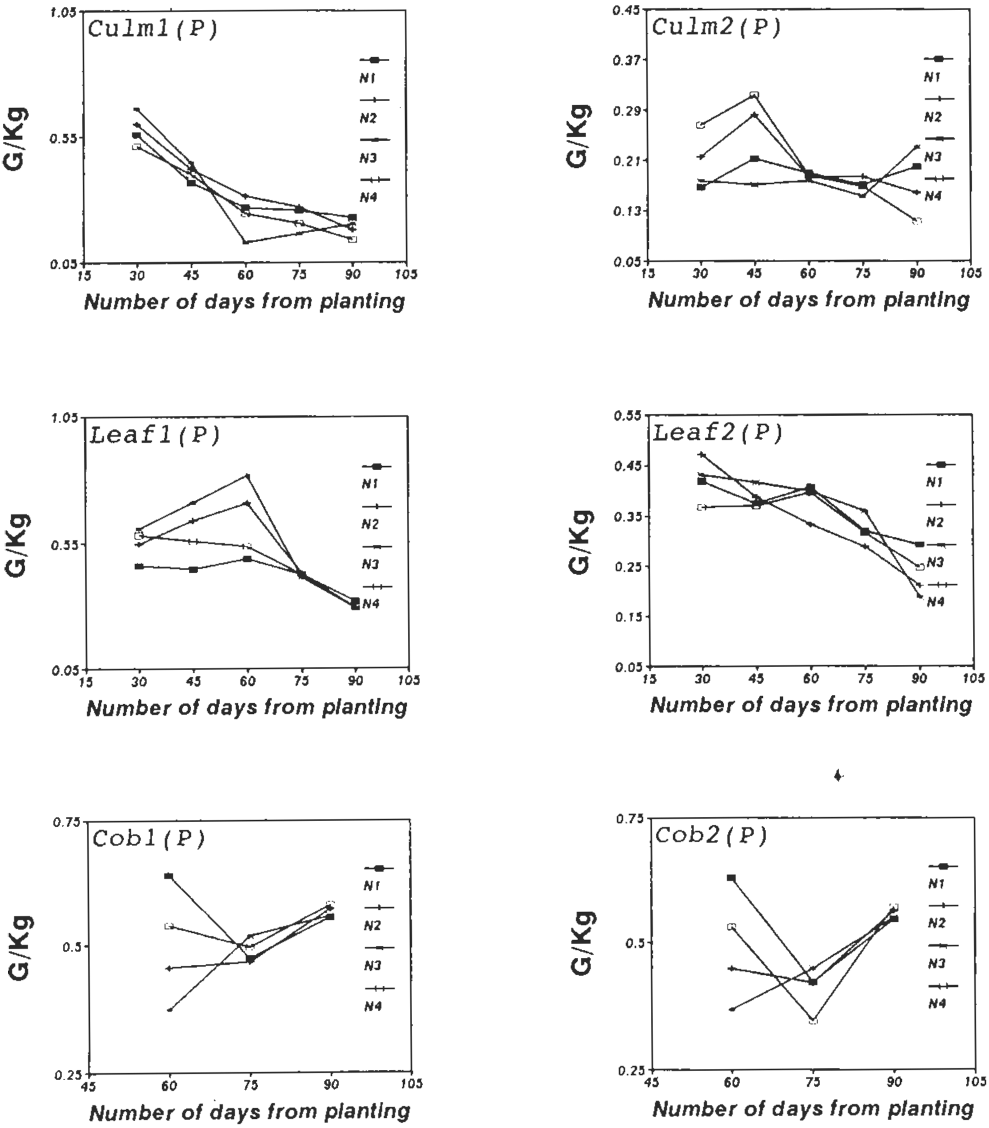

FIG. 4. Annual effect of nitrogen on P content of culm, leaves and cob in 1st(1) and 2nd(2) seasons.

highest at the N_3 level. Positive and significant effects of P application on P accumulation were also limited to leaves in the first and fourth harvests on the spring season (Table 4); whereas those of P on N accumulation were generally not significant (Table 4). Thus these results coupled with those on total biomass and its components clearly indicate that late application of N effects (*i.e.* after 30 or 45 dfp) depend on the season and the dose of P applied at the onset of the season. High doses of P applied at the onset of the season, had no positive effects on consequent harvests of total biomass, its components or in their N and P accumulation at consequent harvests.

Conclusion

Thus the results of the study revealed high significant differences among sampling dates in total dry matter and its components and in the accumulation of both N and P. Total biomass (1325 g m^{-2}) and CBDW (609.5 g m^{-2}) harvested at the end of the spring were respectively 25 and 56% higher than those harvested at the end of autumn (848 vs 488 g m^{-2}). Total biomass averaged over sampling dates, being 404 and 405 g m^{-2} for for the respective season, were statistically similar, offering a better choice in planting corn as forage crop in both seasons or as grain crop in the spring. It is also evident from the results of the study that split application of 225 kg N ha^{-1} in spring and of 150 kg in the autumn together with 150 kg P_2O ha^{-1} applied at sowing proved to be effective for both grain and fodder plantings.

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تأثير التسميد الفوسفاتي والأزوتي المجزأ على إنتاجية المادة الجافة وامتصاص عنصري الأزوت والفسفور في الذرة الشامية خلال فصلي الربيع والخريف بالمنطقة الغربية

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المستخلص . استهدفت التجارب الحلقية التي أجريت خلال الربيع والخريف لعام ١٩٩٢م دراسة تأثير أربع مستويات من الأزوت (١٠٠ ، ١٥٠ ، ٣٠٠ ، ٤٠٠ كجم/ هـ) على هيئة يوريا وزعت على أربعة جرعات متساوية ومستويين من الفسفور (٧٥ و ١٥٠٠ كجم/ هـ) على هيئة سوبر فوسفات أعطيت عند الزراعة ، على نمو وإنتاجية الذرة الشامية ومحتوى الأوزت والفسفور بالأجزاء المختلفة . بلغت الإنتاجية الكلية للمادة الجافة ووزن السيقان بعد ٣٠ و ٤٠ يومًا من الزراعة للموسمين و ٦٠ يومًا للموسم الأول عند المستوى الثالث من الأزوت . كما أظهرت النتائج أن التسميد بمعدل ١٥٠ كجم/ هـ في الخريف و ٢٢٥ كجم/ هـ في الربيع كانت أمر لازم للحصول على أعلى إنتاجية من المادة الجافة والحبوب .

وصلت أعلى محتويات الأزوت والفسفور في الأوراق بعد ٣٠ و ٦٠ يومًا من الزراعة ، ولقد كان لتجزئة المستوى الثالث للأزوت على الدفعات : ٧٥ ، ١٥٠ ، ٢٢٥ كجم/ هـ اعتمادًا على الموسم وموعد الحش ، تأثيرًا معنويًا على الإنتاجية والمحتوى من عنصري الفسفور والأزوت . وقد اقتصر الأثر الإيجابي للمستوى الثاني من الفسفور على وزن السيقان عند ٣٠ يومًا في موسم الربيع وعند ٣٠ و ٤٥ يومًا في موسم الخريف ، أثر معدل الفسفور الثاني سلبًا على وزن الكيزان والوزن الكلي للمادة الجافة عند ٩٠ يومًا من زراعة موسم الخريف .