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Title: CORN (ZEA MAYS L.) YIELDS AS INFLUENCED BY NITROGEN, ROW SPACING AND INTERCROPPED RYEGRASS (LOLIUM MULTIFLORUM)

Abstract approved: Redacted for privacy
Dr. Murray D. Dawson

Two field corn experiments were conducted on a Woodburn silt loam soil near Corvallis, Oregon, in 1972-1973 to investigate the effects of certain soil management practices on the yield and performance of corn (*Zea mays* L.).

Experiment I involved variables that included three corn row spacings (76, 114, and 152 cm) with annual ryegrass (*Lolium multiflorum*) interplanted at three different dates between the corn rows. Average dry matter corn yield of 17.6 m ton/ha obtained in the 76 cm spaced rows decreased by 16% as the row spacing increased to 114 cm. Increasing the row spacing from 114 to 152 cm did not affect corn yield. Corn yield was reduced when grass was interplanted in the widely spaced corn rows. A 35% corn plant yield decrease resulted when grass was planted on May 25 in the 152 cm wide corn rows as

compared with the 76 cm row spacing. A further 15% reduction in corn yields occurred when ryegrass intercropped in the 152 cm rows was compared with yield from 76 cm rows which had no grass intercrop. Intercropping with ryegrass had no adverse effect on corn yield provided that such grasses were planted on July 24 or October 7 in the 76 cm spaced corn rows.

Previous field history and the relatively high nitrogen taken up by the combined corn and grass crops suggested that the experimental area contained considerable residual soil nitrogen.

Experiment II aimed at elucidating the effects of rate and method of applied nitrogen have on the yields from differently spaced corn. A 14% increase in dry matter yield of corn was obtained when row spacing was reduced from 91 to 61 cm. Moisture loss due to evaporation from the soil surface in the wide corn rows was higher than in the narrow spaced corn.

Small dry matter corn yield increases were observed as nitrogen fertilizer rates increased from 140 to 196 Kg N/ha or from 196 to 252 Kg N/ha, respectively. The significant corn yield increase resulting from 252 Kg N/ha over the 140 Kg N/ha rates represented an 8% increase. No differences in corn yield were noted due to methods of nitrogen application.

Corn (*Zea mays* L.) Yields as Influenced by Nitrogen, Row Spacing and Intercropped Ryegrass (*Lolium multiflorum*)

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INTRODUCTION

Successful field corn (*Zea mays* L.) production depends on the implementation of a number of soil management practices which combine to give high yields and efficient use of soil and water resources.

There is a vast amount of literature reporting corn response to applied nitrogen, different plant populations and row spacings as well as intercropping systems. Most of the information so acquired in the United States has come from the Midwest or Northern States. Research concerning the influence of these practices on corn yields in the Pacific Northwest is very limited.

The potential for soil erosion in corn fields is often high because the soil is clean cultivated and bare for much of the growing season. Many attempts have been made to establish grass between wide corn rows to minimize erosion. Unfortunately, such a practice is not widely accepted and seems to be of little economic value because of greatly reduced corn yields. Available information suggests that the success or failure of the corn-grass intercropping system is primarily related to the degree of competition offered by the grass. From this standpoint, the practice of intercropping corn with grass may be satisfactorily achieved if the grass is planted after a good stand of corn has previously been developed. This would provide a better competitive position for corn and reduce the competition from a grass intercrop. However, corn row spacing, moisture and soil fertility level must be properly integrated in order to achieve high corn yields and a satisfactory grass intercrop.

The objectives of the present investigation were as follows:

1. To study the influence of planting methods and time of planting a cover crop on corn yield.
2. To investigate the influence of varying rates of nitrogen fertilization on corn yields,
3. To examine planting methods and nitrogen fertilization on corn yield,

REVIEW OF LITERATURE

The response of corn (*Zea mays* L.) to various management practices has long been recognized and the number of investigations reported in the literature is vast. Considerable controversy has prevailed relative to the influence of row spacing, nitrogen fertilization and intercropping practices on corn yields. Not infrequently conflicting results have been reported. In spite of the very considerable amount of research conducted in the United States, particularly in the Midwest, comparatively little research aimed at elucidating soil management practices important in the growing of field corn in the Pacific Northwest has been carried out.

Row Spacing

Conflicting results have been reported by numerous investigators regarding the effects of corn row spacing. Bryan *et al.* (1940), Stickler and Laude (1960), and Giesbrecht (1969) reported no corn yield response to changes in row spacing. With optimum plant population, significant corn yield increases have been observed with a decrease in row spacing (Mederski *et al.*, 1965 and Shibles *et al.*, 1966). These authors suggested the superiority of narrow spacing in terms of improved utilization of light energy. Colville (1968) conducted an experiment to examine the influence of plant spacing and population on aspects of micro climate within eco-systems. He concluded that light was the only factor influenced significantly by the planting pattern. The results showed that inadequate plant population inefficiently used light energy which in turn increased soil temperature. Such conditions contribute to greater evaporation compared with transpiration water losses. Excessive light reaching the soil surface appeared to contribute to weed growth (Colville et al., 1963). With adequate plant population, narrow spacing increased the utilization of solar energy and substantially increased corn yields. Aubertin and Peters (1961), Yao and Shaw (1964), and Denmead et al. (1962) also reported less net radiation from the soil with corn planted in narrow spaced rows. They (Denmead et al., 1962) estimated that spacing rows narrower than 102 cm (40 inches) could increase the energy available for photosynthesis by 15 to 20%.

Colville (1966) summarized the response of corn to row spacing based on a wide range of conditions by suggesting that a 5% yield increase could be expected by narrowing the spacing from 102 cm to 76 cm and likely another 5% by reducing to 51 cm spacing.

Brown et al. (1970) evaluated the response of two corn varieties to various row spacings at Plains in Georgia. Their results showed that yields of irrigated corn were higher with the 51 cm than the 102 cm spacing. Without irrigation, however, one variety showed no response to the decrease in row width. Recently, Cummins and Dobson (1973) conducted the same experiment in Georgia in the Piedmont and Mountains regions. Their results showed differences in response to row spacings depending upon the location. In the Piedmont, yields were significantly higher for the 51 cm compared to the 102 cm spacing. But, in the Mountains yields were not significantly altered by row spacing.

In Ontario, Canada, Hunter et al. (1970) studied five corn (Zea mays L.) hybrids grown in 91 cm and 46 cm spaced rows using populations of 48,000, 62,000, and 72,000 plants/ha. All hybrids increased in grain yields with each increase in population and with the narrowing of the row spacing. They found that the leaf area index increased with decreasing row spacing. Increases in yields with decreases in row spacing were also reported by Pfister (1942), Hoff and Mederski (1960), Stickler (1964), Stivers et al. (1971), and Lutz et al. (1971).

Inconsistent corn response to changes in row spacing has been reported by Rutger and Crowder (1967). They obtained maximum yields of corn at 88,000 plants/ha. Changing the row spacing from 46 to 92 cm did not influence yields. Similarly, Bryant and Blaser (1968) reported inconsistent effects from changes in row spacing. Highest yields were obtained with 71 cm and 36 cm spaced rows but a 36 cm spacing gave yields similar to those from the 53 cm and 89 cm rows. In Alabama, Doss et al. (1970) reported little difference between the 51 and 102 cm row spacings. Rumawas et al. (1971) reported no differences in corn yields between 50 and 75 cm spaced rows in studies conducted in Indiana. In one instance, Samphantharak (1971), working in Oregon, reported that with 128,000 plants/ha, corn planted in 91 cm spaced rows gave a significantly higher yield than in the 61 cm spaced rows.

Nitrogen Fertilization

Corn production as influenced by nitrogen fertilizer practices has received considerable attention. Increases in yield and water use efficiency have been reported to be associated with an increase in the rate of nitrogen application (Olson et al., 1964 and Robinson and Murphy, 1972).

Anderson (1963) reported that with irrigated corn in Oregon the grain yield responded to nitrogen fertilization when the rate was increased from 67 to 201 Kg N/ha.

Jung et al. (1972) concluded from studies conducted in Wisconsin that corn grain yields increased from added nitrogen fertilizer up to 168 Kg N/ha. In Illinois, Welch et al. (1971) showed that there was generally little additional yield response when nitrogen rates exceeded 201 Kg N/ha. Similarly, McIntosh and Varney (1972), in Vermont, reported that each additional increment of nitrogen consistently increased yields. Plots receiving 224 Kg N/ha yielded

5.51 tons/ha more than plots receiving no nitrogen. However, 168 Kg N/ha gave the same yield as 224 Kg N/ha rate.

The beneficial effect of nitrogen applied as a side dressing was suggested by Canthem and Williamson (1920). They recommended side dressing nitrogen when the corn was between 60 and 90 cm tall.

In studies conducted by Olson (1971) in Nebraska delaying the nitrogen application until a well established crop root system was developed usually afforded the most efficient utilization of the applied nitrogen. In earlier experiments, Olson et al. (1960) showed that the high recovery of side dressed nitrogen by corn was a significant factor in yield response. Furthermore, the high nitrogen recovery was due to less nitrogen loss by either leaching or volatilization.

According to Turner (1967) in Western Washington, a high population of 82,000 plants/ha suffered severe nitrogen deficiency when only 56 Kg N/ha was applied. However, increasing the nitrogen level to 224 Kg N/ha failed to give additional yield increase when compared with the 168 Kg N/ha rate. These results supported the findings reported by McIntosh and Varney (1972).

Corn Cropping System

Many attempts to reduce erosion through corn cropping systems including crop rotation, minimum or no tillage, corn-sod and intercropping systems have been reported.

Adams et al. (1970) conducted a field experiment in Georgia to determine the effect of cropping systems on corn. They showed that corn yield increased when corn was grown in a rotation with grass or a legume. Frequently the four year grass/legume sod was followed by a corresponding number of years in corn. They (Adams et al., 1970) indicated that both the green manure and sod-based cropping systems reduced soil and water losses as compared with continuous corn. Adams and Barnett (1965) noted that both run off and soil loss are neligible from grass sod. Moody et al. (1965) suggested that row crops could be established on sod crops but that water and nutrients must be adequate for both crops.

Jones et al. (1968), Blevins et al. (1971), and Carreker et al. (1972) reported that a higher yield was obtained from no till corn in a grass sod system. To reduce competition for water between the sod and corn, the sod was killed or retarded by mechanical or chemical means. Carreker's et al. (1972) work revealed that without irrigation, corn and live grass (fescue) exhausted all available soil water during June, and the corn died. With irrigation, corn yields were directly proportional to nitrogen levels and inversely proportional to the amount of live sod. Grain yields ranged from 140 Kg/ha with 112 Kg N/ha on live sod to 9,980 Kg/ha with 448 Kg

N/ha supplied on killed sod treatments. They suggested that the excellent corn yields in the grass sod showed that corn can be grown on the sloping fields of the Piedmont and related areas without causing serious soil erosion.

Cover crops or intercrops have been suggested as a compromise between traditional rotations (including a sod crop) and a grain crop monoculture (Triplett, 1962). Intercropping corn with legumes or grasses suggests that the corn row spacing should be widened to allow light to fall on the intercrop seedlings. Stringfield and Thatcher (1951) suggested that seeding ryegrass in early July in standing corn was successful in corn rows spaced 150 to 175 cm where soil productivity was high.

Kurtz et al. (1952) showed that, in a corn intercropping system, competition occurs primarily for water and mobile nutrient such as nitrogen. Without nitrogen fertilizer, legumes and grasses competed severely with the corn. They indicated that ryegrass was sufficiently dense to control weeds. With nitrogen and water high corn yields were obtained. A sufficiency of nitrogen and water, however, did not completely eliminate competition between corn and the intercrops. Corn yields under the conventional system usually exceeded those under the intercrop system by about 15% (Kurtz et al., 1952).

Triplett (1962) reported that techniques which favor the development of an intercrop such as widely spaced corn rows and early seeding dates for the intercrop, tend to decrease corn yields. The results of his experiment indicated that some grass and legume species significantly depressed corn yields.

A synopsis of the literature cited indicates that at relatively high plant populations narrow spaced corn (about 60 cm) appears to give a higher yield than corn planted in wider rows. Plants in the narrow spaced rows appear more efficient in the utilization of light energy.

High corn yields seem to be related to the application of nitrogen fertilizer as a side dressing with a small percentage of the nitrogen applied as a preplanted fertilizer. Frequently a nitrogen rate equivalent to 160 Kg N/ha appears near optimum. However, rates as high as 224 to 280 Kg N/ha have sometimes given the most satisfactory responses. An evaluation of the nitrogen fertility program for the particular crop-soil system is required before optimum nitrogen rates can be precisely stated.

Interplanting of grass or legume between widely spaced corn rows often results in a depression in corn yields. A few techniques have been used to kill or retard the grass intercrop and thus maintain high corn yields. Such practices have met with only limited success even when efforts have been made to supply adequate water and nitrogen to the corn crop.

MATERIALS AND METHODS

Experiment I
Corn Row Spacing and Intercropped Ryegrass

The experiment was conducted on a Woodburn silt loam soil located on the Hyslop Agronomy Farm near Corvallis, Oregon. Chemical analysis (Roberts et al., 1971) of a composite soil sample from the plot area is given in Table 1.

Table 1. Chemical analysis of the surface 15 cm of soil on the plot area.

pH	P ppm	K (meq/100 gm)	Ca (meq/100 gm)	Mg (meq/100 gm)	Total bases (meq/100 gm)	Percent O. M.	Percent N
5.8	117	0.60	10.4	0.88	11.9	3.00	0.17

Nutrients were applied as ammonium nitrate (34% N) and ammonium sulfate (20% N, 24% S), concentrated super phosphate (45% P_2O_5), and potassium chloride (60% K_2O) to provide rates equivalent to 224 Kg N and 67 Kg S, 22 Kg P, and 55 Kg K per hectare, respectively. The fertilizer was broadcast over the entire experimental area and raked into a prepared seed bed one week before planting. A pre-emergence herbicide (Ramrod) was applied at a rate equivalent to 2.24 Kg/ha. In addition, hand hoeing was carried out when the corn was about 50 days old.

Soil moisture status was monitored by means of gypsum resistance blocks installed at 30, 60, and 90 cm depths at each of the three representative locations in the experimental area. Procedures for installation of gypsum blocks are described by Shearer (1963). Readings obtained on these blocks were used as a guide in deciding when to irrigate. The meter readings were taken twice a week and the irrigation water was applied when the average water suctions at 30 cm depth reached approximately 5 bars. Irrigation water was uniformly applied over the whole area through hand moved sprinkler lines. The sprinkler was a reaction driven type with a single nozzle.

A 3 x 4 factorial arrangement consisting of three corn row spacings with ryegrass interplanted at four dates between corn rows was used. It was designed in completely randomized blocks with three replications. An early corn variety (PX 446) and annual ryegrass (*Lolium multiflorum*) were used in the study. The corn row spacings and ryegrass planting dates utilized in the experiment are presented in Table 2.

The individual plot size was 457 x 609 cm. This size allowed four to eight rows per plot depending on the row spacing. The corn seeds were planted thicker than needed with a Planet Junior seeder on May 24, 1972. A month later, plants were thinned by hand to provide a stand of 69,000 plants/ha in all treatments. Only one plant per hill was retained and the distance between hills in each treatment was adjusted to achieve the desired plant population. Ryegrass seed was broadcast and raked into the soil at a rate equivalent to 45 Kg/ha between corn rows at dates indicated in Table 2.

Table 2. Corn row spacings and ryegrass planting dates used in Experiment I.

Symbols	Descriptions
SP_1	Corn planted in 76 cm rows
SP_2	Corn planted in 114 cm rows
SP_3	Corn planted in 152 cm rows
RY_0	No ryegrass planted
RY_1	Ryegrass planted on May 25, 1972
RY_2	Ryegrass planted on July 24, 1972
RY_3	Ryegrass planted on October 7, 1972

The two center rows of corn were harvested by hand on October 4, 1972 when the grain was in the early dent stage. Stalks cut just above the soil surface providing the plant material for green weight determination. Dry matter samples consisted of six stalks randomly selected which were chopped into short lengths, bagged with the ears and weighed. The sample was then dried at 70° C in a forced-air oven for 48 hours and reweighed and the dry matter content was then calculated. The grain was shelled and weighed separately. Weights of shelled grain so obtained were used to calculate grain yield and percentage for each treatment.

Dried stover and grain samples were separately ground in a Wiley mill, then passed through a one millimeter screen. These samples were again dried at 70° C for 24 hours and readied for Kjeldahl nitrogen analysis (Roberts et al., 1971).

Ryegrass was harvested when seed heads first appeared. The first ryegrass planting was harvested on October 11, 1972 while the second and third plantings were harvested on March 22, 1973. A sampling grid (24 x 24 cm) was used to identify the harvested area which was then cut with a hand clipper. Six grid areas per plot were randomly selected for harvest. Green weights were recorded for each treatment and yield samples were then dried at 70° C for 48 hours for moisture determination. Ryegrass dry matter yields were computed for each treatment. Plant samples were ground in a Wiley mill and redried at 70° C for 24 hours prior to total nitrogen determination (Roberts et al., 1971).

The data were statistically analysed. When significant differences among treatments were indicated by the F test, the least significant differences (LSD) at 5% and 1% levels were computed for paired mean comparisons as described by Steel and Torrie (1960).

Experiment II
Row Spacing and Nitrogen Fertilization

Experiment II was conducted adjacent to and concurrently with

Experiment I on the Hyslop Agronomy Farm. Chemical analysis (Roberts et al., 1971) of a composite soil sample from the plot area is given in Table 3.

Table 3. Soil chemical analysis of the surface 15 cm of soil on the plot area for field Experiment II.

		meq/100 gm					
pH	P ppm	K	Ca	Mg	Total bases	Percent O. M.	Percent N
5.8	110	0.60	10.8	0.77	12.2	3.00	0.13

A seed bed was prepared one week before planting. Similar fertilizer materials as described in Experiment I were broadcast and incorporated into the soil to provide 22 Kg P and 55 Kg K per hectare, respectively. Pre-emergent applications of 2.24 Kg/ha of each atrazine and ramrod were applied for weed control. No subsequent tillage was carried out. Irrigation scheduling was based on gypsum plug readings using the methods described in Experiment I.

An experimental design consisting of a 2 x 3 x 2 factorial in completely randomized blocks with three replications was utilized. Variables studied included two spacings with three rates of nitrogen fertilization and two methods of nitrogen application (Table 4).

Table 4. Corn row spacings, rates and methods of nitrogen fertilizer application used in Experiment II.

Symbols	Description
SP_1	61 cm row spacing
SP_2	91 cm row spacing
N_1	140 Kg N/ha
N_2	196 Kg N/ha
N_3	252 Kg N/ha
M_1	Split nitrogen application (Top dressed)
M_2	Split nitrogen application (Side dressed)

Individual plot size of 366 x 609 cm allowed for four to six corn rows per plot depending on the row spacing. A late maturity corn variety (Pioneer 3773) was planted on May 5, 1972 with a hand operated, hill dropping cornplanter. Four to five grains were planted in each hill. After forty days the plants were thinned to provide a population of 72,000 plants/ha using two plants per hill. The number of hills in each row were adjusted to provide the desired plant population appropriate for each treatment.

At planting, fertilizer nitrogen (ammonium sulfate) at a rate equivalent to 56 Kg N per hectare was broadcast uniformly over the entire experimental area. The remainder of the nitrogen fertilizer was applied as ammonium nitrate in two ways (M_1 and M_2) forty days after planting at rates which supplied a total of 140, 196, and 252 Kg N/ha (N_1, N_2, N_3), respectively. Fertilizer nitrogen for the broadcast (M_1) treatments was uniformly applied between the corn rows leaving approximately 15 cm on each side of the rows and raked into the soil. In the side dressed treatments (M_2) the nitrogen fertilizer was banded 10 cm deep and 15 cm from the corn row with hand equipment.

Corn was harvested when the grain was in the early dent stage on September 25, 1972. Statistical analyses of both corn plant dry matter and shelled grain yields were carried out as described in Experiment I.

RESULTS

Experiment I
Corn Row Spacing and Intercropped Ryegrass

The mean yields of corn, shelled grain and ryegrass as influenced by corn row spacing and ryegrass planting date are presented in Table 5.

Yield of Corn Plants

Corn plant yields as affected by row spacing and ryegrass planting date are reported in Table 5. Analysis of variance (Appendix 1) indicated that both row spacing and ryegrass planting date significantly influenced the dry matter corn yield. Corn yields ranged from 9.21 to 18.94 metric tons/ha (mton/ha). Moreover, the interaction between row spacing and ryegrass planting date was also significant at the 5% probability level.

The highest corn plant yields were obtained for the narrow row (76 cm) spacing (SP_1) compared to the wider spacing. An average yield decrease of 16% resulted from increasing row spacing from 76 cm (SP_1) to 114 cm (SP_2). This amounted to a 2.37 mton/ha decrease. The average corn yield decrease as increasing row spacing from 114 to 152 cm was not significant.

The effect of early ryegrass planting (RY_1) on corn yield was

Table 5. Mean yields of corn, shelled grain and grass.

Treatments	Whole corn plants dry matter (mton/ha)	Percent dry matter	Shelled grain dry matter (mton/ha)	Grass dry matter (mton/ha)	Total yield corn + grass (mton/ha)
SP_1RY_0	18.65	30.84	6.74	--	18.65
SP_1RY_1	14.38	29.18	4.74	0.84	15.22
SP_1RY_2	18.57	30.75	6.35	1.24	19.81
SP_1RY_3	18.94	31.66	6.67	0.44	19.39
SP_2RY_0	15.93	29.69	6.20	--	15.93
SP_2RY_1	14.13	34.90	4.79	1.16	15.26
SP_2RY_2	14.82	30.93	5.36	1.56	16.38
SP_2RY_3	14.75	32.09	4.94	0.30	15.04
SP_3RY_0	14.75	32.82	6.50	--	14.75
SP_3RY_1	9.21	29.79	4.00	1.75	10.99
SP_3RY_2	15.12	32.64	6.40	2.32	17.46
SP_3RY_3	15.31	31.60	6.79	0.42	15.73
$LSD_{.05}$	2.16		1.60	0.21	2.16
$LSD_{.01}$	2.93		2.17	0.29	2.93
Percent CV	8.00		16.00	13.00	8.00

considerably influenced by row spacing. The greatest decreases in the yields of corn plants occurred with the narrowest (76 cm) and widest row spacings (152 cm).

Ryegrass planted on July 24 (RY_2) or October (RY_3) appeared not to affect corn plant yields compared to plots where no ryegrass was planted. Therefore, the absence or presence of ryegrass did not affect corn yield provided that the grass was not planted at the same time as the corn. When ryegrass and corn were planted at the same time (as in the RY_1 treatments) competition resulted and corn yields were greatly reduced. For the narrow spaced rows (76 cm) the corn plant yield decreased from 18.65 to 14.38 mton/ha for the May 25 grass sowing. For the wide row spacing (152 cm) the early seeding of ryegrass reduced the corn plant yield from 14.75 to 9.21 mton/ha.

It should be noted that neither corn row spacing nor ryegrass planting dates affected the corn plant dry matter percentage (Table 5).

Corn Grain Yield

Corn grain yield expressed as the dry weight of the shelled grain is presented in Table 5. Analysis of variance (Appendix 2) indicated that ryegrass planting dates markedly influenced the grain yields. However, neither row spacing nor the interaction between ryegrass planting date and row spacing had any significant effect on the yield of grain.

Corn grain yields ranged from 4.74 to 6.79 mton/ha. Corn grain yield, like corn plant yield, was significantly lowered when ryegrass was planted at the early May 25 seeding date. At the other ryegrass sowing dates grass did not affect the grain yields adversely. Thus, the presence of ryegrass did not affect either corn plant or grain yields provided the corn and ryegrass were not planted at the same time.

The effect of row spacing on grain yields was not significant. Changes in yield as related to the changes in row spacing were inconsistent. The average grain yields for 76 cm, 114 cm, and 152 cm rows were 6.13, 5.32, and 5.92 mton/ha, respectively.

Ryegrass Yield

Ryegrass yields as influenced by ryegrass planting date and row spacing of corn are presented in Table 5. Analysis of variance (Appendix 3) indicated that corn row spacing and grass planting date significantly influenced ryegrass yield. It should be noted that the ryegrass was harvested on different dates.

Ryegrass dry matter yields varied greatly from 0.03 to 2.32 mton/ha depending on the treatment. The highest yield was obtained from the second grass sowing of July 24 (RY_2). At this date the corn was about 100 cm tall. Grass in this treatment was harvested the following March. Grass yield from the early sowing which was harvested in the fall was low by comparison with the July 24 sowing. Wider row spacing of corn favored higher grass yields. When grass was seeded as late as on October 7 after the corn was harvested (RY_3) and harvested in March, grass yields were uniformly low.

Total Yield

The total dry matter from combined grass and corn yields are presented in the last column of Table 5. Analysis of variance (Appendix 4) revealed that both the corn row spacing and the ryegrass sowing dates significantly influenced the combined dry matter yields at the 1% probability level. Moreover, there was a significant interaction between row spacing and grass sowing date on the total dry matter produced.

It should be noted that the maximum grass yield obtained was only 2.32 mton/ha (SP_3RY_2) while corn dry matter yield approached 19 mton/ha (SP_1RY_3).

The highest combined grass and corn yield of 19.81 mton/ha was achieved with the second planting date (July 24) of ryegrass in the narrow row spacing (SP_1RY_2) of corn. When corn and grass were planted together the lowest yield of 10.99 mton/ha was obtained with the widest corn row spacing (SP_3RY_1). This represented an 8.82

mton/ha decrease from the best treatment in terms of total dry matter production.

On the average, the wider the corn row spacing the lower the dry matter yield. However, increasing row spacing from 76 to 114 cm had a more pronounced detrimental effect on total dry matter yield than increasing row spacing from 114 to 152 cm. The total dry matter yield of corn plus grass was also affected by the ryegrass planting dates. The early May 25 grass sowing (RY_1) resulted in a significantly lower total dry matter yield.

The effect of ryegrass sowing dates on total yield of corn plus grass varied with corn row spacings. This was indicated by the significant interaction noted between these treatments. The second ryegrass sowing (July 24) into widely spaced corn rows (SP_3RY_2) gave significantly higher yields than the rows where no grass was sown (SP_3RY_0). However, in the 76 cm and 114 cm row spacings no differences in yield were observed between the conventional (RY_0) and corn-grass intercrop systems (RY_2 and RY_3).

Relationship Between Corn Plant Yields and Yields of Corn Grain

It should be noted that corn plant dry matter production was affected by both corn row spacing and planting date of ryegrass. Only ryegrass planting date influenced grain yield. Regression analysis between corn plant and grain yields indicated a highly significant correlation coefficient of 0.78 (Figure 1). Thus, the differences in grain yield as affected by ryegrass planting dates may be reasonably estimated from the differences in the corn plant dry matter produced.

Nitrogen Uptake by Various Plant Components

The nitrogen contents of corn stover and grains, and grasses are presented in Table 6. Analysis of variance are given in Appendix Tables 5 and 6. The dry matter yield of stover was calculated by subtracting grain yields from the whole plant yields. Percents nitrogen in the stover and grain were not significantly different among treatments. Nitrogen in the grass, though not high in the first planting (RY_1 treatment) decreased in the late plantings. It should be noted that the early grass planting (RY_1) was harvested in the fall and the other grass plantings were harvested in the following spring.

The nitrogen yield of the various crop components are also presented in Table 6. Nitrogen yield varied from 50.02 to 134.42 Kg N/ha and from 65.20 to 116.35 Kg N/ha for stovers and grains, respectively. Nitrogen in the grass varied from less than 10 Kg N/ha (RY_3 treatments) to more than 50 Kg N/ha (SP_3RY_1). In general, grains and stovers yielded considerably more nitrogen than

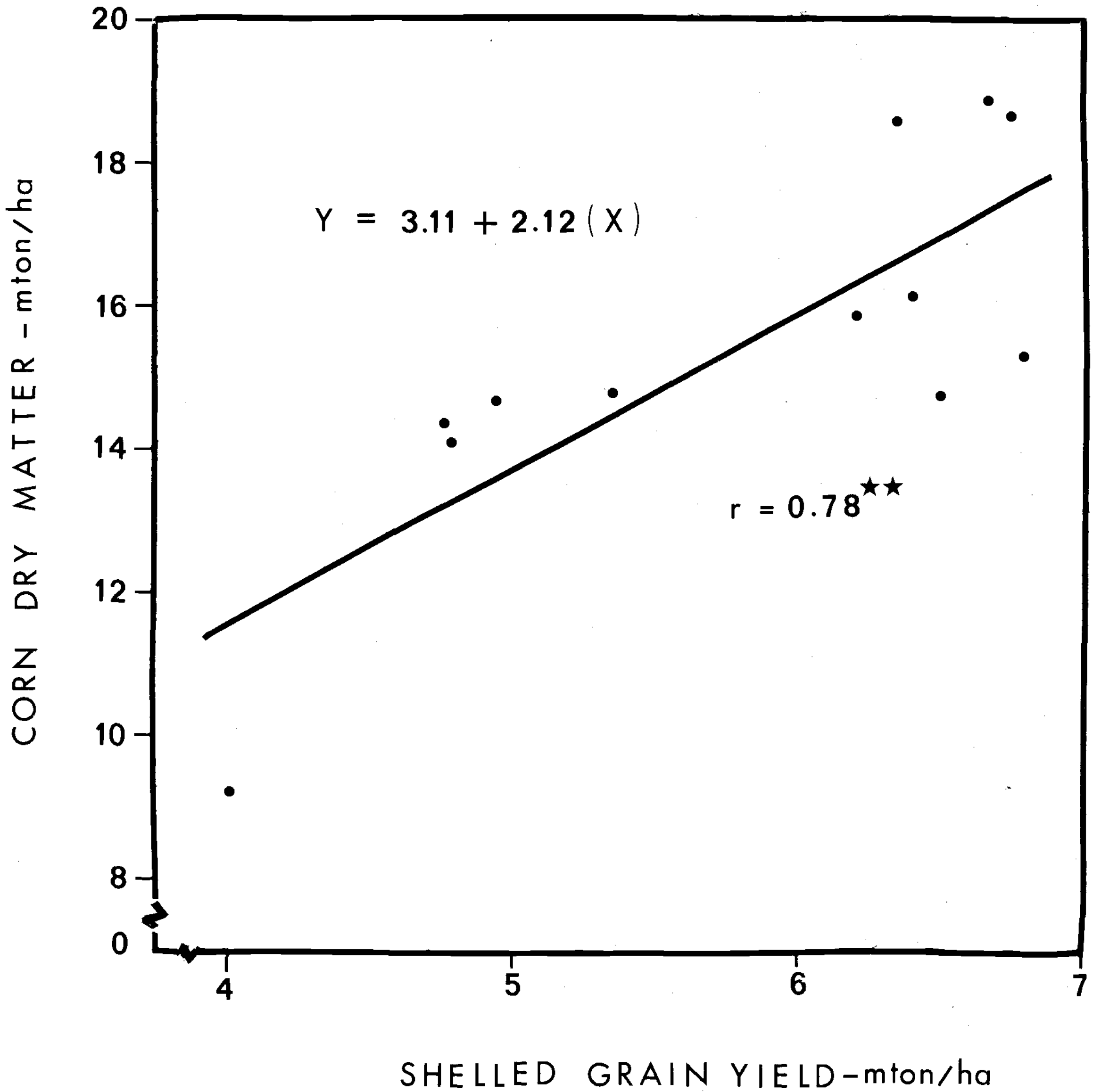

Figure 1. Relationship between corn dry matter and shelled grain yield.
** Significant at the 1% probability level.

Table 6. Nitrogen uptake by various plant components as influenced by corn row spacing and ryegrass planting date.

Treatments	Dry matter			Percent nitrogen			Nitrogen yield			Total N uptake (Kg N/ha)
	Stover	Grain (mton/ha)	Grass	Stover	Grain	Grass	Stover	Grain (Kg N/ha)	Grass	
SP_1RY_0	11.90	6.74	--	1.09	1.47	--	129.82	99.08	--	228.90
SP_1RY_1	9.64	4.74	0.84	0.98	1.56	2.30	94.47	73.94	19.32	187.73
SP_1RY_2	12.22	6.35	1.24	1.10	1.59	1.69	134.42	100.97	20.96	256.35
SP_1RY_3	12.27	6.67	0.44	1.07	1.64	1.95	131.29	109.39	8.58	249.26
SP_2RY_0	9.73	6.20	--	1.15	1.65	--	111.90	102.30	--	214.20
SP_2RY_1	9.34	4.79	1.16	1.03	1.62	2.71	96.20	77.60	31.44	205.24
SP_2RY_2	9.46	5.36	1.56	1.19	1.69	1.77	112.57	90.58	27.61	230.76
SP_2RY_3	9.81	4.94	0.30	1.07	1.68	2.03	104.97	82.99	6.09	194.05
SP_3RY_0	8.25	6.50	--	1.14	1.79	--	94.05	116.35	--	210.40
SP_3RY_1	5.21	4.00	1.75	0.96	1.63	3.02	50.02	65.20	52.85	168.07
SP_3RY_2	8.72	6.40	2.32	1.14	1.55	1.75	99.41	99.20	40.60	239.21
SP_3RY_3	8.52	6.79	0.42	1.14	1.59	1.95	97.13	107.96	8.19	213.28
$LSD_{.05}$		1.60	0.21	ns	ns	0.21				
$LSD_{.01}$		2.17	0.29	ns	ns	0.29				
Percent CV		16.00	13.00	9.00	6.00	7.00				

grass. However, the yield of nitrogen in the grass from the wider row spacing and early seeding of grass (SP_3RY_1) was as high as in the stover. This was due to the low corn yield obtained in this treatment (SP_3RY_1).

Data in Table 6 also indicate that the removal of nitrogen by the crops increased as yield increased. As percent nitrogen among treatments varied little this suggests that total nitrogen removed by the crops was closely related to the yield.

Experiment II
Row Spacing and Nitrogen Fertilization

Corn Dry Matter Yield

The corn yields as influenced by row spacing, rate, and method of nitrogen application are presented in Table 7. The analysis of variance (Appendix 8) indicated that yields were affected by both row spacing and rates of applied nitrogen fertilizer. However, there was no significant difference between the two methods of split nitrogen application.

Corn plant dry matter yields varied from 19.07 to 25.59 mton/ha. The data in Table 7 indicated that higher corn plant yields were obtained from the narrow row spacing (61 cm) (SP_1) in the presence of the heavy nitrogen fertilizer application (252 Kg N/ha) (N_3). Yields decreased with the wider row spacing (91 cm) (SP_2).

Table 7. Corn plant and shelled grain yields as influenced by row spacing, rate and method of nitrogen application.

Treatments*	Corn plants		Corn grains	
	Dry matter (mton/ha)	Percent dry matter	Shelled grain dry matter (mton/ha)	Percent grain
$SP_1N_1M_1$	21.39	31.74	9.88	46.19
$SP_1N_1M_2$	23.07	33.69	10.55	45.73
$SP_2N_1M_1$	20.16	32.16	10.46	51.88
$SP_2N_1M_2$	19.07	31.65	9,17	48.09
$SP_1N_2M_1$	22.62	32.67	10.33	50.10
$SP_1N_2M_2$	22.65	32.91	11.03	48.70
$SP_2N_2M_1$	20.23	32.38	10.60	52.40
$SP_2N_2M_2$	19.61	31.20	10.19	51.96
$SP_1N_3M_1$	24.16	32.95	10.68	44.21
$SP_1N_3M_2$	25.59	30.83	10.27	40.13
$SP_2N_3M_1$	20.67	30.90	9.26	44.80
$SP_2N_3M_2$	20.20	32.87	10.30	50.99
$LSD_{.05}$	3.19		1.97	
$LSD_{.01}$	4.34		2.68	
Percent CV	8.80		11.40	

*The description of the treatments is presented in Table 4, page 16.

It appeared that the rate of nitrogen application did not affect the yield of corn plants at the wider row spacing. Broadcast and side dressed nitrogen gave similar corn plant yield results (M_1 and M_2).

Average corn plant yields for each row spacing at various rates of applied nitrogen are shown in Figure 2. Corn yields obtained from the 61 cm spaced rows were significantly higher than those planted in the 91 cm spaced rows for all rates of nitrogen application. There was a 14% increase in dry matter yield in favor of the 61 cm over the 91 cm spaced rows.

The pattern of corn yield response to applied nitrogen fertilizer is presented in Figure 2. Yield gradually increased as rate of applied nitrogen increased regardless of row spacing. A significant corn yield response was obtained by increasing rate of applied nitrogen from 140 to 252 Kg N/ha. A slight but non-significant response to nitrogen was noted when the nitrogen rate was increased from 140 to 196 Kg N/ha. Average yields recorded by 140, 196, and 252 Kg N/ha were 20.94, 21.28, and 22.67 mton/ha, respectively.

Differences in corn plant dry matter yield between the two methods of nitrogen application (Table 8) were not significant.

The similarity of corn response to applied nitrogen fertilizer regardless of whether side-dressing or broadcasting was used is shown in Figure 3. It should be noted in this study that an initial broadcast application of nitrogen fertilizer was applied prior to

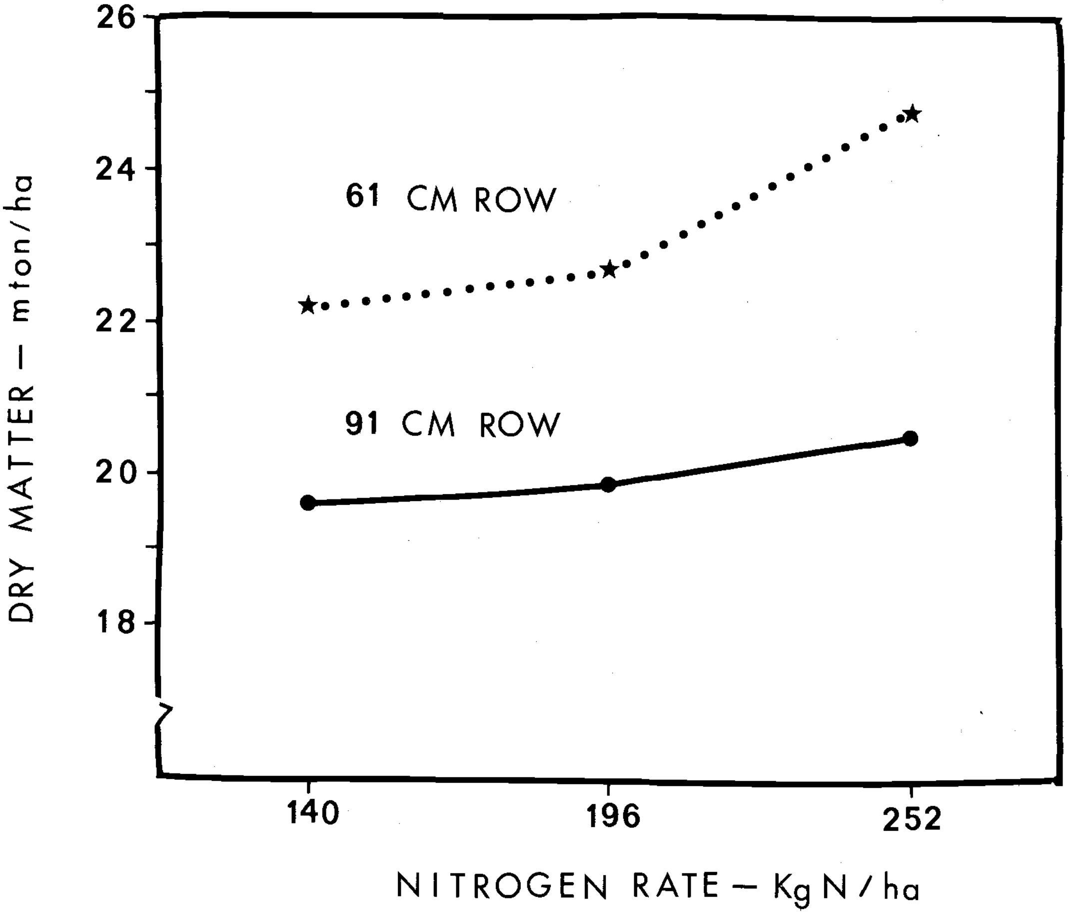

Figure 2. Corn plant yield as influenced by row spacing and rate of nitrogen fertilizer application.

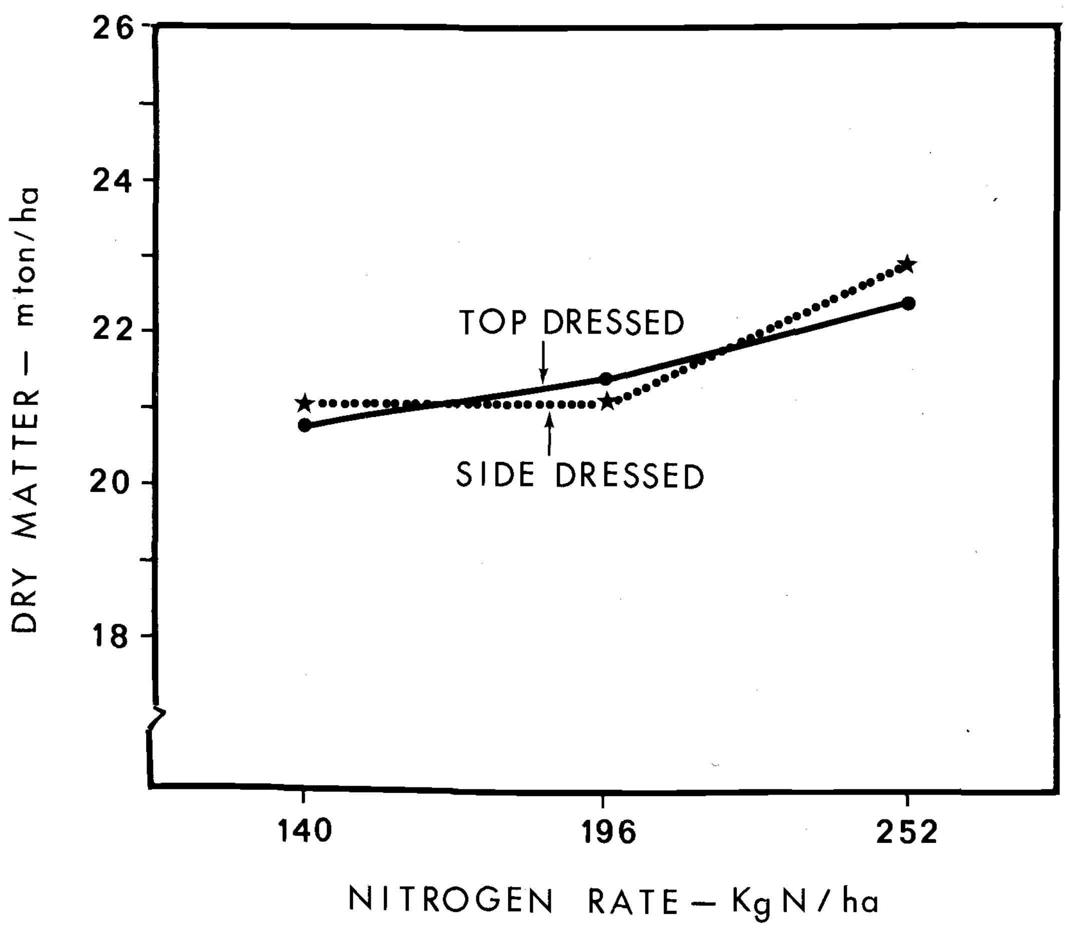

Figure 3. Corn plant yield as influenced by rate and method of nitrogen fertilizer application.

planting to the entire plot area prior to the side dress (M_2) and broadcast treatments (M_1).

Table 8. The effects of row spacing and method of nitrogen application on corn plant dry matter yield (mton/ha).

	Corn Plant Dry Matter Yield (mton/ha) Corn row spacing	
Nitrogen Split Application	61 cm (SP_1)	91 cm (SP_2)
Top dressed (M_1)	22.73	20.35
Side dressed (M_2)	23.76	19.64

There was not a significant difference in percent dry matter in the corn plants among treatments. Neither row spacing or rate and method of nitrogen applied affected the dry matter percentage of the corn plants.

Corn Grain Yield

Mean corn grain yields for the various treatments are presented in Table 7. These yields varied from 9.17 to 11.03 mton/ha, but significant differences of grain yields among the different treatments were not recorded (Appendix 9). Thus neither row spacing nor rate and method of nitrogen application affected the corn grain yield.

The average percentage grain (shelled basis) for all treatments was 47.93% (ranged from 44.21 to 52.40%). One treatment ($SP_1N_3M_2$) gave a low shelling percentage of 40.13%.

Relation Between Corn Dry Matter and Grain Yields

While corn plant dry matter yield was markedly influenced by row spacing and nitrogen rates, shelled grain yield remained unaffected by these treatments. Under such circumstances it was not surprising to note the poor correlation ($r = 0.44$) obtained in the regression analysis between corn grain and corn plant dry matter yields (Figure 4). This low correlation contrasted with the significant correlation obtained in Experiment I between corn dry matter and shelled grain yield.

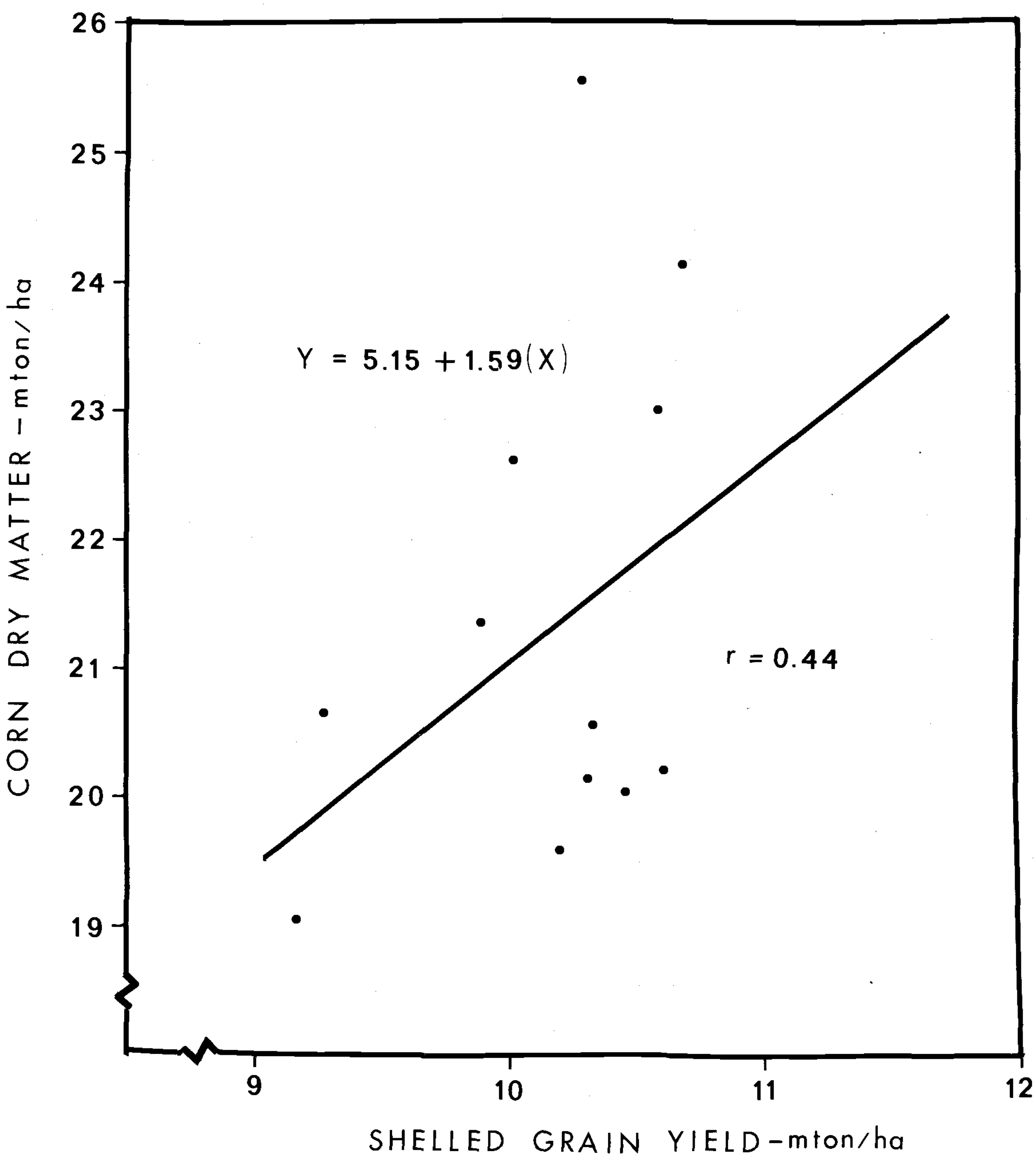

Figure 4. Relation between corn plant dry matter and shelled grain yield.

DISCUSSION

For purposes of discussion, the results obtained in the two Experiments will be considered together.

While there has been much work published relative to the influence of row spacing on either grain or silage corn production, few reports indicate how these two parameters vary simultaneously. Silage and grain yields responded differently to the changes in row spacing used in these experiments. Narrow row spacings of 61 and 76 cm resulted in higher corn plant yields than wider spacings. Corn dry matter production as obtained in Experiment I was significantly greater in the 76 cm compared to the 114 cm and 152 cm spaced rows. In the second Experiment corn plants spaced at 61 cm produced 14% more dry matter than corn from the 91 cm spaced rows. In neither case, however, did corn grain yield vary with row spacing.

One plausible explanation for the higher dry matter corn plant yields in the narrower rows was the likelihood of improved solar energy interception. As the row spacing increased the number of plants per unit length of row increased correspondingly to achieve the same plant population. Relatively close spacing of corn plants in the rows resulted. For instance, in the 91 cm spaced rows with a plant population of about 70,000 plants/ha, spacing between plants in the row was only 15 cm. In contrast, corn planted in 61 cm spaced rows had a spacing of about 23 cm in the row. Thus, plant distribution in the narrow rows is more nearly equidistant in all directions and the individual plants are more uniformly distributed over the entire area. It is suggested that the interception of solar light is favored by narrow spaced corn, while competition induced by mutual shading occurs in the wide spaced corn. Certainly, such beneficial effects of narrow row spacing would probably contribute to the increase in dry matter yield. Denmead et al. (1962) estimated that decreasing corn rows from 102 cm to 61 cm increased the energy available to the crop for photosynthesis by 15 to 20%. Similarly, Colville (1968) concluded that light was the only significant factor influenced by the method of planting. It is likely that for the Pacific Northwest region, where cloudy days often characterize the growing season, limitation of light might readily limit corn yield.

A change in the radiant energy distribution by varying row width could also affect the relative magnitudes of evapo-transpiration. Corn planted in wide rows does not provide a complete crop cover. Such a condition would favor warmer soil temperatures and greater loss of water by evaporation from the soil surface. It is interesting to note that soil moisture was maintained at a relatively high level in this study. Soil moisture tensions (in Experiment II) at 60 cm and 90 cm depths were below 3.0 bars throughout the growing season and were similar in both narrow and wide corn row spacings.

It is likely that corn roots are capable of utilizing soil moisture at 60 - 90 cm depths, which suggests that soil moisture was not a limiting factor in this experiment. However, marked differences in soil moisture stress at 30 cm depth was observed between the narrow and wide corn row spacings (Figure 5). As the season progressed, average moisture tension values recorded from plugs located in 91 cm spaced corn were considerably higher than from the 61 cm rows. Such observations combined with the high yield from the 61 cm row spacing, suggest there was greater moisture evaporation from the soil surface of plots where corn was grown in the wider spaced rows resulting in lower water use efficiency. Yao and Shaw (1964) found that evaporation was significantly reduced with closer row spacing (61 cm compared to 102 cm) and this led to a considerable increase in the efficiency of water use. Similar results were also reported by Aubertin and Peters (1961), and Denmead et al. (1962).

Though the intercropping of ryegrass in wide corn rows produced relatively high grass yields it could not compensate for the great reduction in corn yield (Figure 6). The combined influence of close planting of corn in the wide rows, together with the relatively vigorous grass stand provided a highly competitive effect on corn. Thus, when all ryegrass planting dates were considered, the plant corn dry matter production from the wider spaced rows was

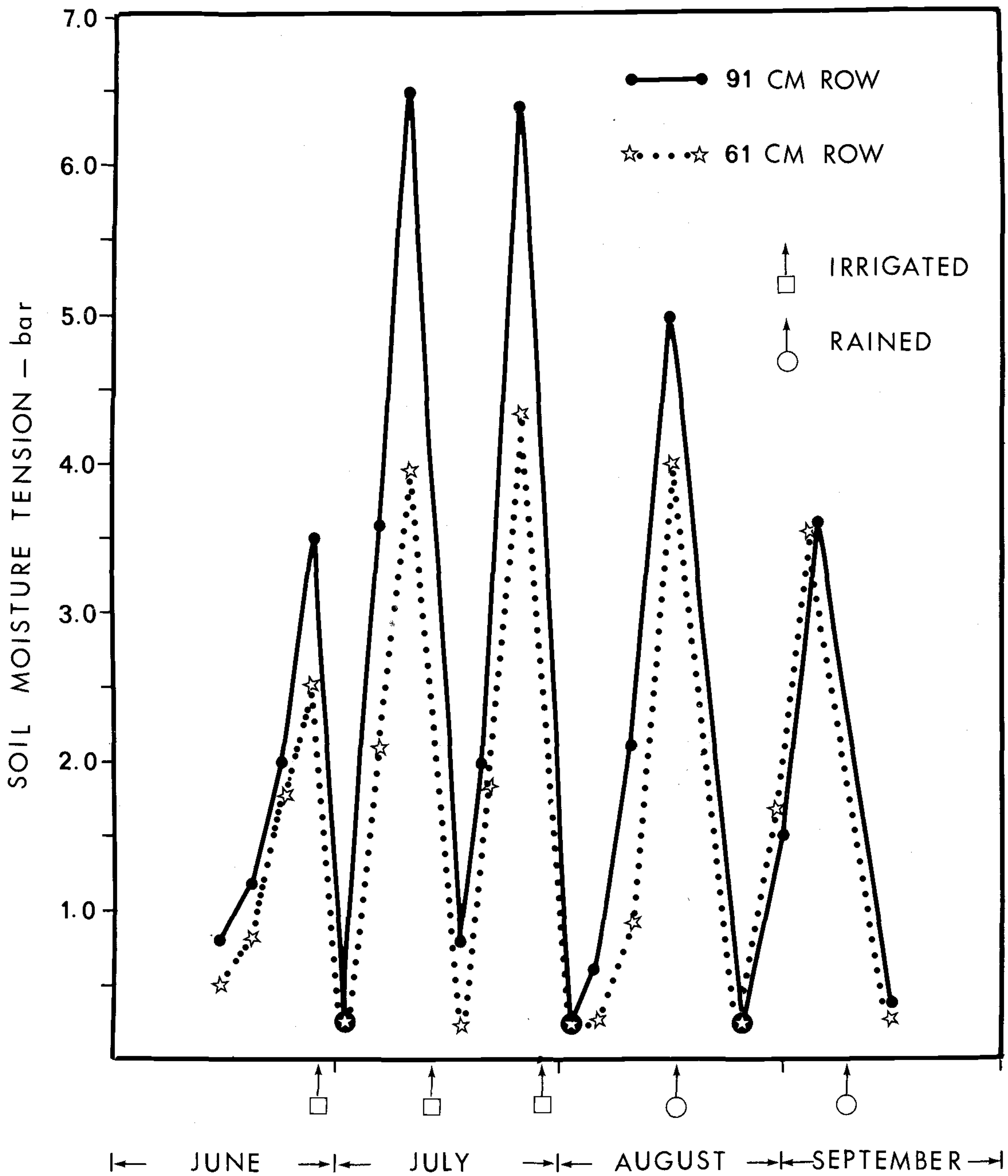

Figure 5. Soil moisture tension at 30 cm depth between narrow and wide corn row spacings during the growth of corn.

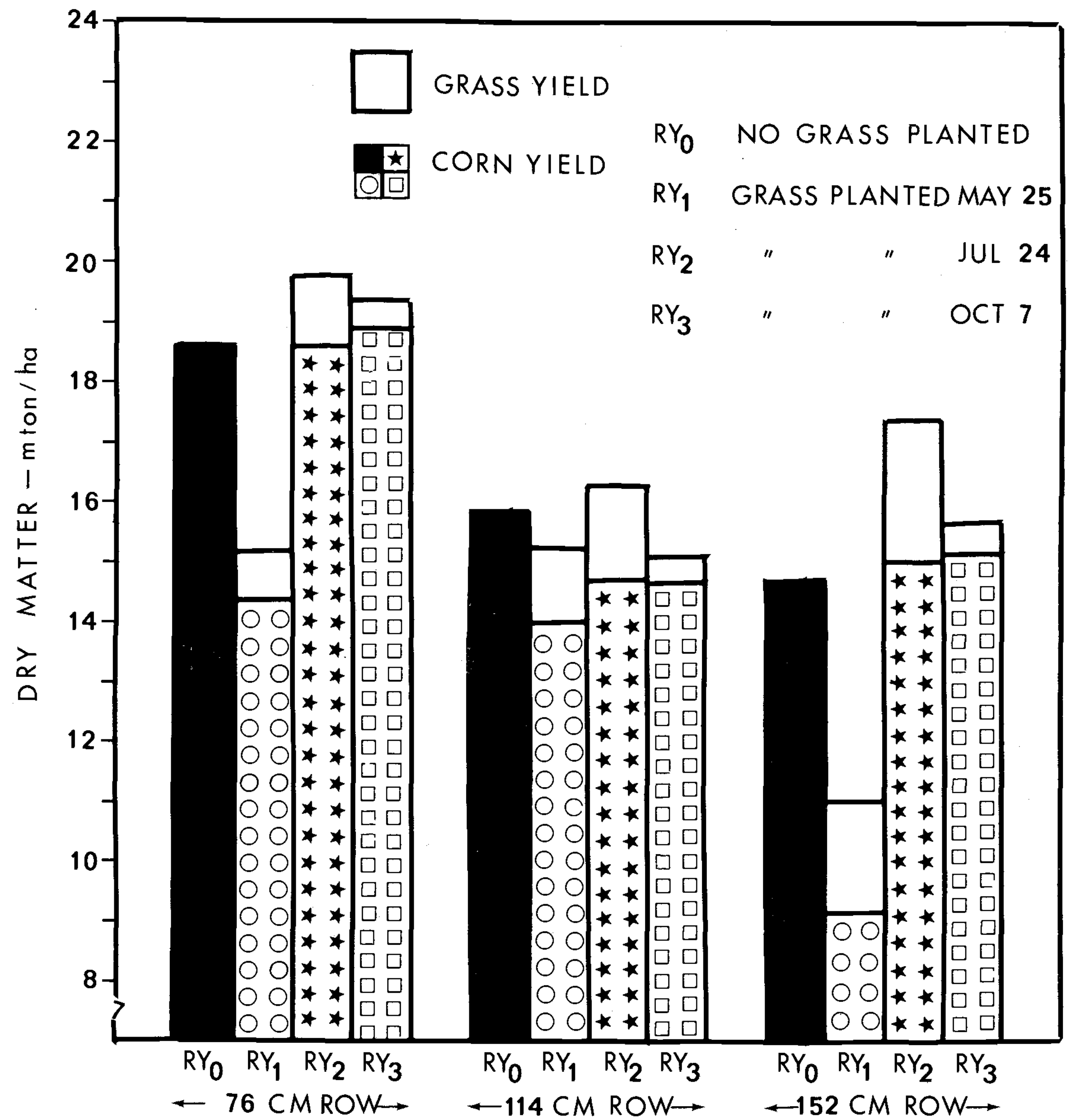

Figure 6. Combined corn plant and ryegrass dry matter yields as influenced by corn row spacing and grass planting date.

reduced more than 20% compared to the yields obtained from the narrow row spacing. Such results suggest a real problem concerning interplanting grass in widely spaced corn rows. Interplanting of ryegrass in narrow spaced corn, however, is not subject to the same limitation, rather grass planting date appears the factor determining the success of this practice. Early seeding of ryegrass markedly depressed corn yield. Even at the high rate of nitrogen (224 Kg N/ha) and with adequate soil moisture, severe competition between corn and the intercrop was observed when the ryegrass was seeded early. Corn plant yield in the narrow row spacing-early grass seeding, corn-grass intercropping system decreased about 23% (Figure 6) over the non-intercropped plots. On the other hand, intersowing of ryegrass in late July or October had no adverse effect on corn yield provided narrow row spacing was used. Unfortunately, ryegrass yields in the narrow corn row spacing were low. These results suggest the difficulty of maintaining high corn yields on the one hand and obtaining a good ryegrass cover crop on the other. Intercropping of grass in corn would appear to have some limitations, however, it could be valuable in those areas where erosion is a severe problem. Alternately, early winter green feed available from the interplanted grass after the corn was harvested would be an asset to the livestock man. Further investigations are needed in this instance to examine the practicality of sowing ryegrass in say 40 day old corn planted in wide rows.

Results from Experiment II indicated that boosting nitrogen fertilizer rate from 140 to 252 Kg N/ha resulted in about 8% dry matter yield increase (with no increase in grain yield). In terms of economic return, it appeared that 140 Kg N/ha of fertilizer was close to optimum corn crop production on this Woodburn soil. These results tend to support those obtained by other investigators. Jung *et al*. (1972) reported that following summer side dressing of corn, grain and tissue yields increased up to the 168 Kg N/ha rate of nitrogen application. No further yield increases from a 224 Kg N/ha application were noted. On irrigated corn in Nebraska, Olson (1971) found that the economic maximum return was obtained with 90 Kg N/ha applied as a summer side dress. No further grain yield increase was noted when the nitrogen fertilizer application was increased to 180 Kg N/ha.

In the present experiments it is likely that adequate nitrogen was available to the corn at 140 Kg N/ha rate regardless of whether the nitrogen was broadcast or side dressed. The mobility of nitrate in soil is well known. It appears that either by mass flow or diffusion, nitrogen was equally available to corn regardless of whether nitrogen was broadcast or banded.

As might be expected the total nitrogen removed by the corn and grass crops was closely related to the total dry matter produced. The total plant nitrogen uptake so computed is presented in Table 6. It is of interest to note the total plant nitrogen uptake ranged from 168 to 256 Kg N/ha representing an appreciable amount of nitrogen removed from the soil. In view of the fact that 140 Kg of applied nitrogen fertilizer gave near optimum corn yield, it suggests that the experimental site contained a considerable amount of residual nitrogen. Past history of the experimental area included two years of corn preceeded by nine years of alfalfa. Likely the residual nitrogen from a nine year stand of alfalfa was substantial.

Herron et al. (1968) found that corn roots are capable of extracting substantial amounts of nitrate to a soil depth of 180 cm. Gass et al. (1971) noted that residual nitrogen accumulated at various depths during corn experiments. They found an accumulation of inorganic nitrogen of 409, 468, and 582 Kg N/ha, within a depth of 180 cm from corn plots which had received for three successive years 85, 165, and 250 Kg N/ha, respectively. These accumulation occurred despite the removal of nitrogen by a crop that averaged over 9,300 Kg grain per hectare. Average annual nitrogen removals in the grain were 112, 174, 162, and 176 Kg N/ha on plots which annually received 0, 85, 165, and 250 Kg N/ha of nitrogen fertilizer, respectively. Thus if nitrogen removal in the grain was of the same magnitude as the stover as indicated in this present study (Table 6) this would result in more than 300 Kg N/ha (in grain + stover) taken up by corn plant where 250 Kg N/ha of fertilizer had been applied. In view of the Gass et al. findings it would appear that the maximum uptake of nitrogen by the combined corn and grass crops obtained in this study (Table 6) of 256 Kg N/ha where 224 Kg N/ha was applied was a reasonable value.

Previous experiments (Klock and Calhoun, 1966) conducted on Woodburn soil near the experimental site used in this study showed that in the absence of applied nitrogen fertilizer the average corn dry matter yield was about 11.2 mton/ha. If one were to assume a plant nitrogen percentage of 1.2 which was the average percent plant nitrogen in this present study, the 11.2 mton/ha dry matter yield would remove an equivalent of 114 Kg N/ha. By using this value for the control proceed to calculate the approximate utilization of applied nitrogen for each treatment from the following equation:

$$\% \text{ Utilization of applied N} = \frac{\text{N in grain + stover - N in control}}{\text{N applied}} \times 100$$

The percentage utilization of applied nitrogen fertilizer so calculated is presented in Table 9.

Percentage utilization of fertilizer nitrogen as presented in Table 9 should be interpreted primarily as relative differences due to the treatments. Different environmental conditions and percent plant nitrogen used in above equation (page 43) preclude Table 9 data being interpreted as absolute values.

Table 9. Percentage utilization of applied nitrogen as influenced by corn row spacing and ryegrass planting date.

	Corn Row Spacing		
Ryegrass Planting Date	76 cm (SP_1)	114 cm (SP_2)	152 cm (SP_3)
No ryegrass planted (RY_0)	38	31	29
Grass planted May 25 (RY_1)	20	27	11
Grass planted July 24 (RY_2)	50	39	42
Grass planted Oct 7 (RY_3)	47	22	31

It is apparent (Table 9) that the percentage of applied nitrogen ranged from 11 to 50%. Narrow row spaced corn (76 cm) generally utilized applied nitrogen more efficiently than the wider spacings. A grass intercrop increased the recovery of applied nitrogen except for early planting (May 25) where poor utilization of fertilizer nitrogen was associated with low yields. Olson (1971) reported the recovery of split applied nitrogen fertilizer in the order of 50% following an application of 90 Kg N/ha. He noted that utilization efficiency decreased as the rate of nitrogen fertilizer applied was increased. Thus the relatively low percentage utilization of applied nitrogen obtained in this study (Table 9) probably resulted from the high rate of nitrogen fertilizer (224 Kg N/ha) used in the experiment.

These findings indicate the need for assessing nitrogen status in the soil before accurate fertilizer recommendation can be made. This would provide not only a basis for predicting the maximum economic return but also guard against potential eutrophication problems arising from readily leached excess soil nitrates.

SUMMARY AND CONCLUSIONS

Two field experiments were conducted concurrently on Woodburn silt loam soil on the Hyslop Agronomy Farm near Corvallis, Oregon to investigate the influence of corn row spacing, date of interplanting ryegrass between corn rows and rates and methods of nitrogen fertilizer application on irrigated corn yield.

Corn responded similarly in both experiments to changes in row spacing. Corn dry matter yields were significantly increased as row spacing was decreased. In contrast, the yield of corn grain was not affected by differences in row spacing.

The higher corn dry matter yields for the narrow spaced rows likely resulted from the more nearly equidistant orientation of corn plants resulting in increased utilization of light energy. Soil moisture measurements at various depths on the experimental plots indicated a greater moisture loss from the soil surface due to evaporation in the wide spaced corn rows resulting in less water use efficiency.

Corn row spacing and ryegrass interplanting date are critical factors in determining the success of a corn-grass intercropping system. Corn yield was reduced significantly when grass was interplanted between the widely spaced corn. In spite of the apparent adequacy of both nitrogen and water, competition between grass and corn was observed. When grass was planted at the same time as corn in the wide 152 cm spaced rows a near 50% corn plant yield decrease compared to the narrow spacing no intercrop treatments occurred. When grass was planted into the narrow row spaced corn in late July, the corn yields did not decline. Where corn yields were not significantly reduced by the grass, protective cover during winter likely reduces leaching of nutrients and provides a potential source of early winter pasture.

Though there was a small gradual increase in corn yield as the rates of nitrogen fertilizer were increased up to 252 Kg N/ha, the findings suggest that nitrogen rate of 140 Kg N/ha was sufficient or close to optimum production.

These findings indicate the need for assessing nitrogen status in the soil before accurate fertilizer recommendations are made. This would provide not only the maximum return but also guard against potential eutrophication problems arising from readily leached excess soil nitrates.

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APPENDIX

Appendix Table 1. Analysis of variance for corn plant dry matter yield.

Source of variation	DF	SS	M. S.	F
Replication (R)	2	17.63	8.85	5.43*
Treatment (T)	11	227.16	20.65	12.67**
SP	2	102.11	51.06	31.33**
RY	3	94.92	31.64	19.41**
SP x RY	6	30.20	5.03	3.09*
R x T	22	35.75	1.63	
Total	35	280.54		

* Significant at .05 probability level.
**Significant at .01 probability level.
Percent C.V. = 8.00

Appendix Table 2. Analysis of variance for corn grain yield.

Source of variation	DF	SS	M. S.	F
Replication (R)	2	2.38	1.19	1.32
Treatment (T)	11	30.68	2.79	3.10*
SP	2	4.15	2.08	2.31
RY	3	20.56	6.85	7.61**
SP x RY	6	5.98	1.00	1.11
R x T	22	19.89	0.90	
Total	35			

* Significant at .05 probability level.
**Significant at .01 probability level.
Percent C.V. = 16.00

Appendix Table 3. Analysis of variance for grass yield.

Source of variation	DF	SS	M. S.	F
Replication (R)	2	0.01	0.01	0.50
Treatment (T)	8	11.38	1.42	71.00**
SP	2	2.20	1.10	55.00**
RY	2	8.11	4.06	203.00**
SP x RY	4	1.07	0.27	13.50**
R x T	16	0.33	0.02	
Total	26			

* Significant at .05 probability level.
**Significant at .01 probability level.
Percent C.V. = 13.00

Appendix Table 4. Analysis of variance for total yield of corn plus grass.

Source of variation	DF	SS	M. S.	F
Replication (R)	2	18.40	9.20	5.68*
Treatment (T)	11	190.98	17.36	10.72**
SP	2	80.72	40.36	24.91**
RY	3	79.37	26.46	16.33**
SP x RY	6	30.90	5.15	3.18*
R x T	22	35.62	1.62	
Total	35	245.00		

* Significant at .05 probability level.
**Significant at .01 probability level.
Percent C.V. = 8.00

Appendix Table 5. Analysis of variance for percent nitrogen in stover.

Source of variation	DF	SS	M. S.	F
Replication	2	0.01	0.01	1.00
Treatment (T)	11	0.16	0.02	2.00
SP	2	0.02	0.01	1.00
RY	3	0.10	0.03	3.00
SP x RY	6	0.04	0.01	1.00
R x T	22	0.15	0.01	
Total	35	0.32		

Percent C. V. = 9.00

Appendix Table 6. Analysis of variance for percent nitrogen in corn grain.

Source of variation	DF	SS	M. S.	F
Replication (R)	2	0.01	0.01	1.00
Treatment (T)	11	0.22	0.02	2.00
SP	2	0.06	0.03	3.00
RY	3	0.02	0.01	1.00
SP x RY	6	0.14	0.02	2.00
R x T	22	0.13	0.01	
Total	35	0.36		

Percent C. V. = 6.00

Appendix Table 7. Analysis of variance for percent nitrogen in grass.

Source of variation	DF	SS	M. S.	F
Replication (R)	2	0.08	0.04	2.00
Treatment (T)	8	5.17	0.65	32.50**
SP	2	0.31	0.16	8.00**
RY	2	4.35	2.18	109.00**
SP x RY	4	0.51	0.13	6.50**
R x T	16	0.26	0.02	
Total	26	5.51		

* Significant at .05 probability level.
**Significant at .01 probability level.
Percent C. V. = 7.00

Appendix Table 8. Analysis of variance for corn dry matter as affected by row spacing, rate and method of nitrogen application.

Source of variation	DF	SS	M.S.	F
Replication	2	7.094	3.547	0.997
Treatment	11	130.369	11.852	3.330**
SP	1	76.659	76.659	21.539**
N	2	26.139	13.070	3.672*
M	1	2.159	2.159	0.607
SP x N	2	11.377	5.689	1.598
SP x M	1	13.457	13.457	3.781
N x M	2	0.262	0.131	0.037
SP x N x M	2	0.317	0.159	0.045
Error	22	78.306	3.559	
Total	35	215.769		

* Significant at .05 probability level.
**Significant at .01 probability level.
Percent C.V. = 8.80

Appendix Table 9. Analysis of variance for shelled grain yields as affected by row spacing, rate and method of nitrogen application.

Source of variation	DF	SS	M.S.	F
Replication	2	4.475	2.238	1.647
Treatment	11	9.989	0.908	0.668
SP	1	1.895	1.895	1.394
N	2	1.823	0.912	0.671
M	1	0.022	0.022	0.016
SP x N	2	0.261	0.131	0.096
SP x M	1	0.646	0.646	0.475
N x M	2	0.636	0.318	0.234
SP x N x M	2	4.706	2.353	1.731
Error	22	29.895	1.359	
Total	35	44.359		

Percent C.V. = 11.40