To the Graduate Council:

I am submitting herewith a thesis written by Donald Craig Jones entitled "The Effect of Awn Removal on Yield and Yield Components in Three Varieties of Soft Red Winter Wheat." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

Vernon H Reich

V. H. Reich, Major Professor

We have read this thesis
and recommend its acceptance:

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Accepted for the Council:

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Graduate Studies and Research

A

THE EFFECT OF AWN REMOVAL ON YIELD AND YIELD COMPONENTS IN THREE VARIETIES OF SOFT RED WINTER WHEAT

A Thesis

Presented for the

Master of Science

Degree

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Donald Craig Jones

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ABSTRACT

A field study was conducted to evaluate the effects of awn removal on yield and yield components in three soft red winter wheat varieties (Triticum aestivum L. em Thell). The three varieties used were Arthur, a tip awned type, S76, and Hart, both fully awned types. Five awn removal treatments, at heading, 1, 2, 3, and 4 weeks after heading (C-0, C-1, C-2, C-3, and C-4, respectively) and a control (C) were used to determine the role that awns contribute to yield in these varieties.

There were significant differences in yield per sample due to awn removal treatments. Awn removal 2 weeks after heading (C-2) gave the highest yield per sample of 70.77 g. This treatment resulted in significantly higher ($P \leq .05$) yields than all other treatments except the control (C) which yielded 64.26 g per sample. The C-2 treatment was also significantly higher ($P \leq .05$) than the other treatments in yield per spike except C-4 and C. C-2 had a significantly higher ($P \leq .05$) number of spikes per sample (74.8) than C-0. The number of kernels per spike was significantly higher ($P \leq .05$) for C-2 than for C-0 and C-3.

Removal of the awns had an affect on hundred kernel weight. C-1 (3.17 g) was significantly lower ($P \leq .05$) than C and all other treatments except C-3 (3.28 g).

C-4 had a significantly lower ($P \leq .05$) test weight than C-0, C-2, and C, 77.4 versus 78.0, 78.4, and 78.3 kg/hl.

There was significant variety X clipping interaction in yield per sample, yield per spike, and hundred kernel weight. In yield per sample and yield per spike the interaction was due to significant variation among the varieties in C-0 and the lack of variety differences in the other treatments. In hundred kernel weight Hart and Arthur reacted much the same to the awn removal treatments, but S76 varied from the response patterns of these two varieties.

Significant variation in yield per sample due to treatment effects did not occur in the tip awned variety Arthur. However, there were significant differences among the treatments for yield per spike in Arthur.

The awn removal treatments had a significant affect on yield per sample in the fully awned variety S76. However, two factors which possibly biased the C-2 effect were the substantial rainfall (> .50 cm) and the high number of spikes per sample in S76.

Significant differences in yield per sample, yield per spike, and hundred kernel weight due to the treatments occurred in Hart, another fully awned variety. The earlier the awn was removed in Hart, the greater the reduction in yield. The one exception to this statement was the C-2 treatment. The rainfall mentioned above was believed to have increased the yields in all three varieties.

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CHAPTER I

INTRODUCTION

Prior to the development of the combine for wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) harvest, there was a demand for awnless varieties due to the physical discomfort attributed to the awn at harvest time. Little notice was given to the possible effects that awns might have on yield. With the onset of mechanized harvest, the physical annoyances of wheat and barley awns at harvest were lessened. Interest then grew as to the effect of the presence or absence of awns on grain yield.

It was understood that chlorophyll containing plant parts were involved in metabolism instrumental to grain development. Experiments were designed to compare the awned and awnless or awn-clipped types of wheat and barley. Numerous articles appeared which examined the effect of awns on yield in hard winter, hard spring, and durum wheats. The data on the effect of awns in soft red winter wheat is incomplete.

The objective of this research was to determine the effect of awn removal on yield per sample, yield per spike, kernels per spike, hundred kernel weight, and test weight in three soft red winter wheat varieties.

CHAPTER II

REVIEW OF LITERATURE

There has long been an interest in the significance of awns on the growth of wheat, barley, and other grasses grown for grain. As early as 1892 Zoebl and Mikosch (33) spoke of the favorable effect of the awn on barley. The following year Von Proskowetz (29) mentioned the importance of the awn to the plant. Interest increased concerning the effects of awns on yield and various yield components.

Watson and Norman (31) studied the causes of differences in grain yield among three barley varieties. The varieties did not differ in leaf area index or in net assimilation rate before spike emergence. This led them to hypothesize that the yield differential was due to photosynthesis in parts of the plant other than the leaves. The hypothesis was strengthened when they found that the awns contributed 10% to the dry matter in the grain.

McDonough and Gauch (12), using radioactive labeled CO_2 in durum wheat, found that at soil moisture levels close to the wilting point, the percentage contribution of awns to kernel weight increased while that of the flag leaf decreased. They concluded this phenomenon explained why awned types outyield awnless types in semi-arid regions, yet show no advantage in humid regions. They also estimated that the awns contribution to total grain dry weight was 41% of that by the entire spike or 12% of that by the entire plant. Evans and Rawson (6) showed that spike photosynthesis in wheat was much higher in awned varieties as compared to awnless, but did not test for the effect of awns on spike photosynthesis per se. Walpole and Morgan (30) stated that differences in growth rates between grains of barley on the same ear were not due to flag leaf assimilate being supplied to the more rapidly growing grain, as had been thought in the past. The differences were due to various amounts of assimilate being supplied by each photosynthesizing awn; the area of which was a major factor in determining respective amounts.

Teare et al. (27), using two isogenic lines of wheat, reported that net photosynthetic rates (mg CO_2 dm^{-2} hr^{-1}) of awned, awnless, and awn-clipped heads were not significantly different, but the amount of photosynthesis per head (mg CO_2 hr^{-1}) was greatest for awned types. This group also compared photosynthetic/respiration ratios of the three types, and the awnless types had a 20% greater water use efficiency than the awned lines. This suggests that awnless wheat types might be favored over awned types in areas of drought stress. However, this experiment was conducted under growth chamber and greenhouse conditions, and this perhaps explains some of the apparent disagreement with other results of field experiments.

Schmid (23) reported that removal of the awns can cause a decrease in kernel weight. Perlitius (17) found that yield reductions resulted from deawning wheat and barley. He investigated the distribution of stomata on various parts of the floret and the effect of removal of awns from the plant. He concluded that the earlier awns were removed, the greater the reduction in yield.

Harlon and Anthony (9) reported that barley plants from which awns had been removed produced only 75% of the yield of normal intact plants. They also found that awnless plants were comparable in yield to plants from which the awns had been clipped. Miller et al. (14) studied the effects of deawning on winter wheat by removing awns at 1 week intervals beginning 7 days before anthesis and continuing until 14 days after anthesis. They concluded deawning decreased the weight of grain, the effects of deawning tended to be lessened as the length of time increased after anthesis.

Similarly, Saghir et al. (20) demonstrated that awn clipping caused a reduction in yield and test weight in barley and wheat. These reductions corresponded with the length of the awn clipped and advancement of the stages of blooming and anthesis. The greatest reductions occurred at anthesis and decreased with advanced growth. Clipping of the awns at anthesis reduced grain yield 20.8% of the control and kernel weight 13.4% of the control.

Michael and Seiler-Kel Bitsch (13), studying cytokinin content and kernel size of barley grain, showed that deawning of the spike caused a reduction in cytokinin content and subsequently smaller seed size. Follow-up work in this area has not been reported.

Zaleski (32) compared awned and awnless progenies of individual plants of some Triticum species, and found the awned plants had heavier ears and a higher kernel weight than the awnless plants. Experiments by Grantham (8) covering 10 years and including 1986 varieties showed an average increase in yield of 3.3 bushels per acre for awned varieties compared to awnless varieties. Also, Clark et al. (4) concluded that longer awned wheat genotypes tended to be associated with higher yields. Hayes (10) studied the differences between awned and awnless varieties of wheat and found that awned types had grain that was longer, plumper, and heavier than grain from awnless types. Conversely, Clark and Quisenberry (5) noticed a yield differential in favor of awnless over awned wheat varieties. This was in contradiction with the majority of research published in the field. However, part of the difference in yield was accounted for by the larger occurrence of shattering in the awned varieties. Rosenquist (19) compared kernels from awned and awnless florets borne on the same F_2 spike and concluded that the presence of awns increased kernel weight progressively going from partial to fully awned.

Schaller and Qualset (22) stated that awns are advantageous in high-yielding environments or when a stress, possibly moisture, occurs after heading. When stress occurs in early ontogeny, there is competition between the awns and initiation and fertility of florets. However, if moisture stress occurs later in development, the assimilatory activities of the awn help minimize the stress. Lamb (11) stated that in dry regions the awned wheat varieties were higher yielding than awnless varieties. He attributed this phenomenon to the fact that the awn reaches physiological maturity just at the time of grain filling, and subsequently the awn supplies the ripening grain with the necessary precusors for greater yield potential. However, he stated that this varies with the variety used. Tandom and Dhillon (26) tested the effects of awns on wheat under moisture stress and demonstrated that awned types generally outyielded awnless types due to an increase in kernel size; hence a greater kernel weight and yield per plot were obtained. Vervelde (28) found that in humid environments with less moisture stress, the yield differences between awned and awnless wheat lines were not significant. Bayles and Suneson (3) reported that awned lines of spring wheat were higher than awnless lines for test weight, yield, and kernel weight, but awned winter wheats were superior to awnless types only for test weight and kernel weight when considered over an environmental range from low to high moisture.

A more accurate method of determining possible differences between awned and awnless lines was developed which utilized isogenic lines. Suneson et al. (25) compared isogenic (awned and awnless) wheat lines of Baart and Onas derived by reciprocal backcrossing. They found that in general the awned types were superior in yield, test weight, and kernel weight under both semi-arid and irrigated conditions. The awned type of Onas was more desirable because of the significant increase in test weight. Similarly, Atkins and Morris (2) studied the effect of awns using 10 pairs of isogenic wheat lines obtained by 10 generations of selfing. It was assumed that a pair of lines was identical phenotypically and genotypically except for awns. The awned types of wheat were superior in yield, test weight and kernel weight when compared to isogenic awnless types in years of drought stress in Texas. In a similar droughty environment Atkins and Finney (1) determined that awned isogenic varieties had a higher test weight while the awnless varieties had a higher bread loaf volume. There was no significant difference in kernel weight.

Patterson et al. (15), using soft red winter wheat, developed 12 pairs of nearly isogenic lines to study the effects of awns on yield. They found that awned wheat types were superior to awnless types for yield, kernel weight, and test weight, especially the first two. The greatest advantage of the awned lines was in the "best wheat producing year" when it was cooler and wetter than normal. In regards to yield, the awn X genotype interaction was as large among lines of common parentage as among lines of different parentage. This suggested that parental source of awns was of no more importance than the interaction of awns X specific genotypes. In regards to test weight, differences between pairs of lines and awn X genotype interaction were highly significant. The awn X genotype interaction again indicated that awns contribute differently in various genotypes. Differences in test weight were not found between lines of common parentage and lines of different parentage, indicating that parental source of awns was not important for this character. In regards to kernel weight, the interaction of awn X genotype was highly significant, suggesting that for this character the awn contribution depends on the genetic background of the variety.

Qualset et al. (18) reported a yield advantage of 6-10% for awned over awnless isogenic wheat lines due to larger kernel size. This was more apparent when tested in semi-arid regions. They reported that in 1961 (a dry year) a regression coefficient of .75 mg/kernel/cm awn was calculated, while in 1962 (an adequate moisture year) a regression coefficient of .56 mg/kernel/cm awn was calculated. The regression coefficients were not significant, but the coefficients follow a type of pattern seen in other experiments which show that a greater portion of the kernel size was contributed by the greater awn length in the drier years. Schaller et al. (21) studied the relative mean yield over several environments for full, half, quarter, and awnless isogenic barley lines. They found a regression coefficient of .69 for kernel weight on awn length, and this is similar to the figure reported earlier by Qualset et al. (18). This regression coefficient suggests a direct linear relationship between awn length and kernel size. Schaller and coworkers speculated that competition for substrate between developing awns and initiation and development of florets may reduce yields in certain stress situations.

Faris (7) found a similar relationship between kernel size and awn length in barley. Even though average linear regression coefficients were about one-half that reported by Qualset et al. and Schaller et al., Faris suggested that awns affect kernel size and florets by developing during the early ontogeny of the plant. Both studies, Faris (7) and Schaller et al. (21), indicate that half-awned varieties had the highest yield. This may be due to the keen competition for nutrients between awn and floret early in development.

Patterson and Ohm (16) concluded that under warm conditions of moisture stress, awned isogenic soft red winter wheat lines outyielded awnless lines due primarily to larger kernel size of awned types. They also stated that awns may contribute differently to kernel weight and test weight in different genotypes, and this may be due to linkage block effects near the awned locus. These linkage block effects may mask positive or negative yield factors which might influence kernel weight and test weight. Another stress condition they studied which allowed the awned types to show superiority in yield was severe wheat rust. They speculated that the greater photosynthetic area afforded by the awns resulted in the greater yield. However, Shannon and Reid (24) demonstrated with isogenic barley lines that under scald stress the advantage of awns versus awnless was more consistently expressed in test weight and kernel weight than in yield.

It is evident that the presence or absence of awns in wheat and barley affect yield and the yield components kernel weight and test weight. When studies were first conducted to determine the effects of awns on various yield components, the consensus was that awnless or deawned types were lower in grain yield than the awned types. The general pattern which was reported revealed that the presence of awns increased the yield variables progressively going from partial to fully awned. It was also determined that under moisture stress, awned types generally had a higher yield, kernel weight, and test weight. Awned types were usually superior for yield under other stress conditions such as scald and rust. The greater photosynthetic area afforded by the awns resulted in greater yield, kernel weight, and test weight.

However, some studies indicated that awned types were not always advantageous. It was observed that a critical time occurred in which a stress factor might nullify the advantageous nature of awns. Several workers showed that under moisture stress competition for substrates early in development between awns and florets reduced yields.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted in 1979-80 at The University of Tennessee Plant Sciences Field Laboratory on Government Farm Road near Knoxville to determine the effect of awn removal at various times on three standard varieties of soft red winter wheat. The three varieties used were Arthur, a tip awned type, Pioneer S76, and Hart, both fully awned types.

Each variety was planted on 10 October, 1980 using a tractor mounted cone planter. The soil type was a Decatur silt loam. Prior to planting the experimental area received 450 kg/ha of 6-12-12 fertilizer applied broadcast. The pH was adjusted to approximately 6.5 by the application of agricultural lime. The plots were top-dressed with ammonium nitrate at a rate of 50 kg/ha of N in early March 1980.

The experiment was conducted as a randomized complete block with three replications and treatments assigned in a factorial arrangement. The experimental unit was 2.7 meters in length with four rows spaced 30 cm apart. There were two sampling units per experimental unit. Each sampling unit consisted of a 60 cm section representative of the entire row chosen from one of the middle two rows of the experimental unit. Awn removal treatments were administered to both sampling units of each variety in every replication. The awn removal treatments consisted of the following: no clip (control), clip at heading, clip 1 week after heading, clip 2 weeks after heading, clip 3 weeks after heading, and clip 4 weeks after heading. Hereafter, the awn removal treatments will be referred to as C, C-0, C-1, C-2, C-3, and C-4, respectively.

Wheat plants were considered to be headed when 80-90% of the spikes were extruded from the boot. The length of awns of the tip awned and fully awned types varied from .60 to 4.50 cm. Scissors were used to remove the awns by clipping on the appropriate date. The awns were clipped at the tips of the lemma and palea so as not to injure these structures. All awns were removed from the base to the apex of the spike.

Awn removal treatments began on 6 May, 1980 and were completed on 11 June, 1980. Each clipping generally required from 3 to 4 days to complete for all varieties and replications. Rain occurred in substantial amounts only from May 17-20 (> .50 cm). Plants were under moisture stress before and possibly after this time period.

The wheat plots were harvested 23 June, 1980 and threshed using a Vogel head thresher. Harvested samples were stored at room temperature and weighed in late August. Data were analyzed using an IBM 360-65 computer. The analyses were done with the primary objective of determining if there were significant differences among clippings for the variables yield per sample, yield per spike, kernels per spike, hundred kernel weight, and test weight.

The component spikes per sample was measured as a check to substantiate that no bias was introduced when the sampling units were designated. The number of spikes per sample would have been determined by the number of plants per sample and the tillering efficiency of each plant. Removal of the awns would have had no effect on this variable since the spikes were formed before awns were clipped.

CHAPTER IV

RESULTS AND DISCUSSION

Tests for deviation from normality were not significant for any of the dependent variables. The variables measured were yield per sample, yield per spike, spikes per sample, kernels per spike, hundred seed weight, and test weight.

Analysis of variance of yield per sample revealed significant differences due to the effects of replications, clippings, and variety by clipping interaction. Duncan's New Multiple Range Test (DMRT) was performed on replications, varieties, clippings, and variety X clipping interaction.

There were significant differences due to replications for the variable yield per sample. It was apparent from visual observation that plants in replication three had less general vigor than those in replications one and two. The data showed mean yields per sample of 66.48 and 62.87 g for replications one and two, respectively. The mean yields per sample of Arthur, S76, and Hart were 58.61, 58.99, and 64.23 g, respectively. However four of the yield component variables measured differed significantly due to varieties. These variables were yield per spike, spikes per plot, hundred seed weight, and test weight (Table 1).

A significant difference for yield per spike was found between Hart (.91 g) and S76 (.79 g). Arthur (.87 g) was not significantly different from either Hart or S76. A significant variety difference in spikes per sample was observed between S76 (73.6) and Arthur

Table 1. Mean Yield Per Sample, Yield Per Spike, Spikes Per Sample, Kernels Per Spike, Hundred Kernel Weight, and Test Weight of Three Soft Red Winter Wheat Varieties.

Variety	Yield Per Sample†	Yield Per Spike†	Spikes Per Sample†	Kernels Per Spike†	100 Kernel Weight†	Test Weight†
	g	g	No.	No.	g	kg/hl
Arthur	58.61 a	.87 ab	66.9 b	26.0 a	3.35 b	78.7 a
S76	58.99 a	.79 b	73.6 a	25.2 a	3.17 c	77.9 b
Hart	64.23 a	.91 a	70.0 ab	26.0 a	3.51 a	77.3 c

†Values within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

(66.9). Hart (70.0) was not significantly different from either Arthur or S76. There were significant differences among varieties in hundred seed weight. Hart (3.51 g) was significantly greater than Arthur (3.35 g), and Arthur was significantly greater than S76 (3.17 g) (Table 1). Significant differences among varieties were also observed in test weight. Arthur (78.7 kg/hl) was significantly different from S76 (77.9 kg/hl), and S76 was significantly different from Hart (77.3 kg/hl) (Table 1).

There were significant differences in yield per sample due to time of awn removal. However, the data revealed significant differences which were not expected based on prior knowledge. Treatment C-2 was not significantly different ($P \leq .05$) from C, but it was significantly higher than C-0, C-1, C-3, and C-4 (Table 2). Except for C-2, these results reveal a pattern reported earlier by Miller et al. (14) and Saghir et al. (20) in that the earlier the awns are removed, the greater the reduction in grain yield. However, C-2 did not align with this pattern. The cause for the unexpectedly high yield per sample for C-2 is puzzling.

One factor which might have caused the increase in yield between C-1 and C-3 is the substantial rainfall (> .50 cm) which occurred immediately following the completion of C-1. Prior to C-1 and through its completion the rainfall was minimal. However, 2 days before initiating C-2, substantial rainfall occurred and continued for 4 days. Rainfall then ceased until all clippings were completed. The validity of this explanation is questionable since it would be expected that C-3 and C-4 should have likewise benefited from the

Table 2. Mean Yield Per Sample, Yield Per Spike, Spikes Per Sample, Kernels Per Spike, Hundred Kernel Weight, and Test Weight Under Different Awn Removal Times.[††]

Treatment	Yield Per Sample[†]	Yield Per Spike[†]	Spikes Per Sample[†]	Kernels Per Spike[†]	100 Kernel Weight[†]	Test Weight[†]
	g	g	No.	No.	g	kg/hl
C	64.26 ab	0.92 ab	69.5 ab	26.9 ab	3.43 a	78.3 a
C-0	55.08 b	0.82 b	67.0 b	24.6 b	3.33 a	78.0 a
C-1	56.10 b	0.80 b	69.6 ab	25.3 ab	3.17 b	77.8 ab
C-2	70.77 a	0.95 a	74.8 a	28.1 a	3.39 a	78.4 a
C-3	57.35 b	0.81 b	70.9 ab	24.7 b	3.28 ab	77.8 ab
C-4	60.07 b	0.86 ab	69.4 ab	25.1 ab	3.44 a	77.4 b

[†]Values within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

[††]Values in the table are the means of three varieties and three replications.

rainfall. Therefore, the physiological explanation for the variation in yield per plot due to C-2 remains unclear.

There were significant differences in yield per spike due to the various awn clipping treatments. Treatment C-2 (.95 g) was not significantly different ($P \leq .05$) from either C (.92 g) or C-4 (.86 g), but all other clipping treatments were significantly different from C-2 (Table 2). Again, C-2 had an unexpected high yield per spike when compared to other clipping treatments and the control. The previous discussion on rainfall mentioned in connection with yield per sample is a possible explanation for the unexpected results. Another possible explanation for the significant effect of C-2 on yield per sample and yield per spike is the yield component spikes per plot. C-2 (74.8) was significantly higher ($P \leq .05$) than C-0 (67.0) in regards to spikes per sample (Table 2). The high number of spikes per sample would obviously increase the grain yield of C-2.

There were significant differences in kernels per spike due to clipping effects. C-2 (28.1) was significantly higher than C-0 (24.6) and C-3 (24.7) (Table 2). The number of kernels per spike was calculated as follows:

$$\text{Kernels per spike} = \frac{(\text{yield per sample}) \times (100)}{(\text{100 kernel weight}) \times (\text{spikes per sample})}$$

It is evident that kernels per spike are directly related to yield per sample as well as weight of kernels and spikes per sample. The author believes that the significant difference due to C-2 is attributable to the significant affect of C-2 on yield per sample. The rainfall reduced the moisture stress in the plants and possibly increased yield. This would increase the number of kernels per spike, based on the relationship mentioned earlier.

Hundred kernel weight was affected by clipping awns. Removing awns 1 week after heading (C-1) significantly ($P \leq .05$) reduced kernel weight when compared to C, C-0, C-2, and C-4, 3.17 g versus 3.43, 3.33, 3.39, and 3.44 g, respectively (Table 2). There was no difference in hundred kernel weight as a result of C-1 versus C-3, 3.17 versus 3.28 g, respectively.

There were significant differences in test weight due to clipping awns. Treatment C-4 (77.4 kg/hl) was significantly lower ($P \leq .05$) than C-0 (78.0 kg/hl), C-2 (78.4 kg/hl), and C (78.3 kg/hl).

Significant differences occurred within the three varieties due to the various awn removal treatments. In Hart, a fully awned type, C (77.15 g) and C-2 (73.92 g) were significantly higher in yield per sample than C-0 (52.15 g) and C-1 (54.32 g) (Table 3). In S76, another fully awned type, C-2 was significantly higher than C (51.27 g) and C-4 (51.90 g). There were no differences among the clipping treatments in Arthur, a tip awned type (Table 3 and Figure 1). It appears that removal of tip awns does not significantly alter processes involved in grain filling.

The author believes that the significantly higher yield per sample of S76 in C-2 is due to the high number of spikes per sample in that clipping treatment. C-2 (82.0) was significantly higher than C-4 (66.7) (Table 4). The high number of spikes per sample would bias upward the yield per sample of C-2 in S76 when compared to other clipping treatments.

Table 3. Mean Yield Per Sample and Yield Per Spike of Three Soft Red Winter Wheat Varieties Resulting From Awn Removal at Different Times.

Variety	Awn Removal Treatment	Yield Per Sample†	Yield Per Spike†
		g	g
Arthur	C	64.37 abcd	0.96 ab
Arthur	C-0	57.75 bcd	0.89 abc
Arthur	C-1	51.30 d	0.85 abc
Arthur	C-2	67.10 abcd	0.95 ab
Arthur	C-3	50.02 d	0.72 c
Arthur	C-4	61.13 abcd	0.86 abc
S76	C	51.27 d	0.74 bc
S76	C-0	55.35 cd	0.75 bc
S76	C-1	62.70 abcd	0.82 bc
S76	C-2	71.30 abc	0.86 abc
S76	C-3	61.42 abcd	0.84 abc
S76	C-4	51.90 d	0.78 bc
Hart	C	77.15 a	1.07 a
Hart	C-0	52.15 d	0.82 bc
Hart	C-1	54.32 cd	0.75 bc
Hart	C-2	73.92 ab	1.05 a
Hart	C-3	60.63 abcd	0.86 abc
Hart	C-4	67.18 abcd	0.95 ab

†Values within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

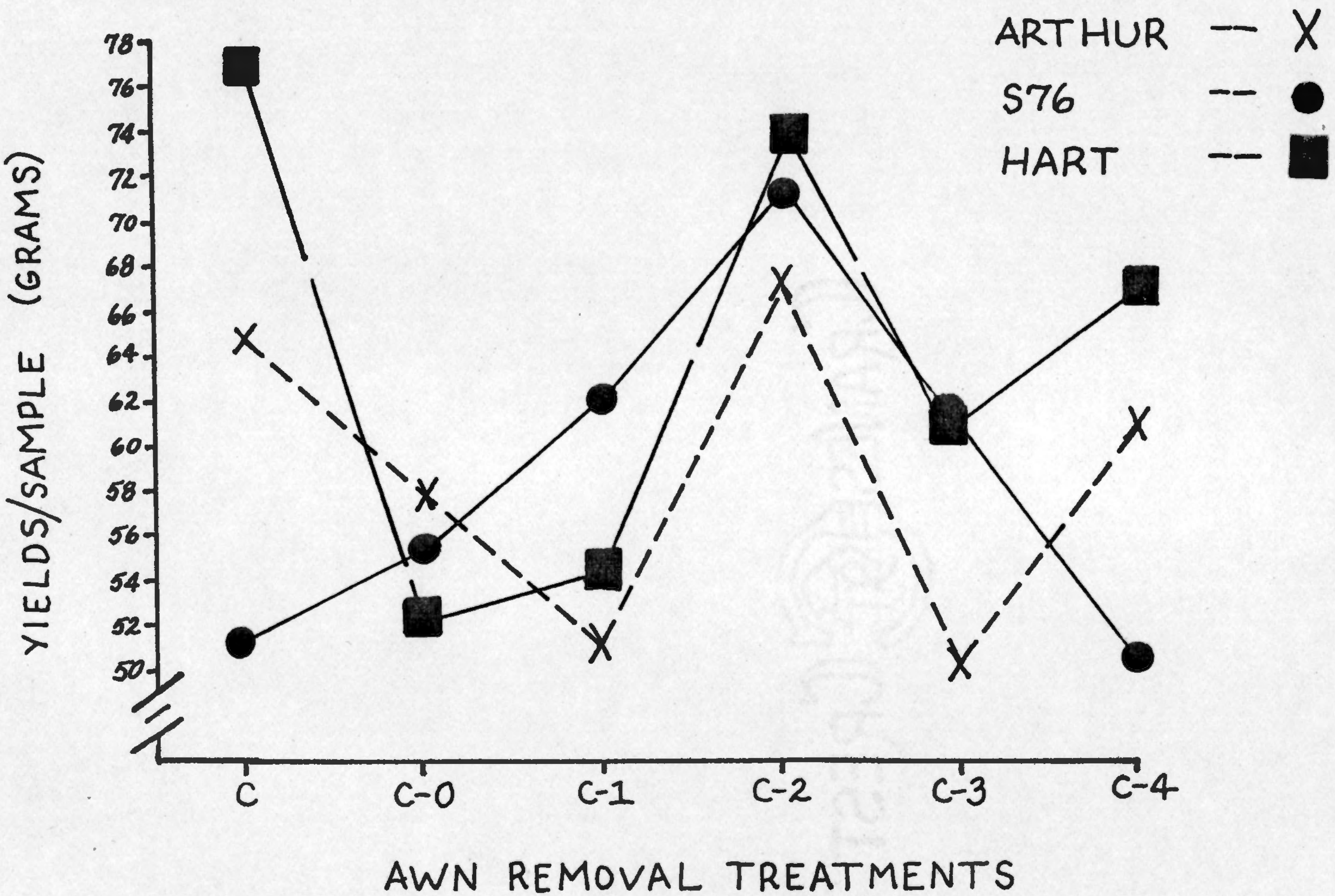

Figure 1. Mean Yield Per Sample of Awn Removal Treatments for Three Varieties of Soft Red Winter Wheat

Table 4. Mean 100 Kernel Weight and Spikes Per Sample of Three Soft Red Winter Varieties Resulting From Awn Removal at Different Times.

Varieties	Awn Removal Treatment	100 Kernel Weight†	Spikes Per Sample†
		g	No.
Arthur	C	3.39 abcde	66.3 bc
Arthur	C-0	3.47 abc	63.7 bc
Arthur	C-1	3.18 cdef	61.3 c
Arthur	C-2	3.43 abcd	70.5 abc
Arthur	C-3	3.21 bcdef	68.3 abc
Arthur	C-4	3.43 abcd	71.5 abc
S76	C	3.26 bcdef	69.7 abc
S76	C-0	3.08 F	73.8 abc
S76	C-1	3.11 ef	75.8 ab
S76	C-2	3.13 ef	82.0 a
S76	C-3	3.15 def	73.8 abc
S76	C-4	3.25 bcdef	66.7 bc
Hart	C	3.63 a	72.5 abc
Hart	C-0	3.45 abc	63.5 bc
Hart	C-1	3.23 bcdef	71.5 abc
Hart	C-2	3.62 a	71.8 abc
Hart	C-3	3.50 ab	70.7 abc
Hart	C-4	3.63 a	70.0 abc

†Values within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

Another reason to question the C-2 effect on yield per sample is revealed in yield per spike. A similar pattern would be expected for clipping treatment effects on yield per sample and yield per spike. In Hart a similar pattern was observed, but not S76. In Hart, yield per spike for C (1.07 g) and C-2 (1.05 g) were significantly higher than C-0 (0.82 g) and C-1 (0.75 g). However, in S76 there were no differences in yield per spikes due to clipping treatments (Table 3 and Figure 2). In Arthur, C (0.96 g) and C-2 (0.95 g) were significantly higher than C-3 (0.72 g), but the author believes this difference is due to the low number of kernels per spike which occurred in C-3 for Arthur. The clipping treatment effect on yield per sample and yield per spike closely parallel in Hart, but the clipping treatment effect on the same two variables in S76 does not parallel. The author believes there was no real clipping treatment effect on yield per sample in S76.

In Hart, removal of awns in early ontogeny apparently limited the amount of photosynthesis which subsequently reduced the yield for C-0 and C-1. It should be noted that the clipping treatment effects on Hart are closely aligned with the general pattern reported by other workers (14, 20); that is the earlier the awns are removed, the greater the reduction in yield. This of course excludes the unusual effect of C-2.

There were also differences in hundred kernel weight within the three varieties due to the treatments. In Hart, C-1 (3.23 g) was significantly lower ($P \leq .05$) than C (3.63 g), C-2 (3.62 g), and C-4 (3.63 g) (Table 4). However, in S76 and Arthur there were no differences among C-1 and the other clipping treatments.

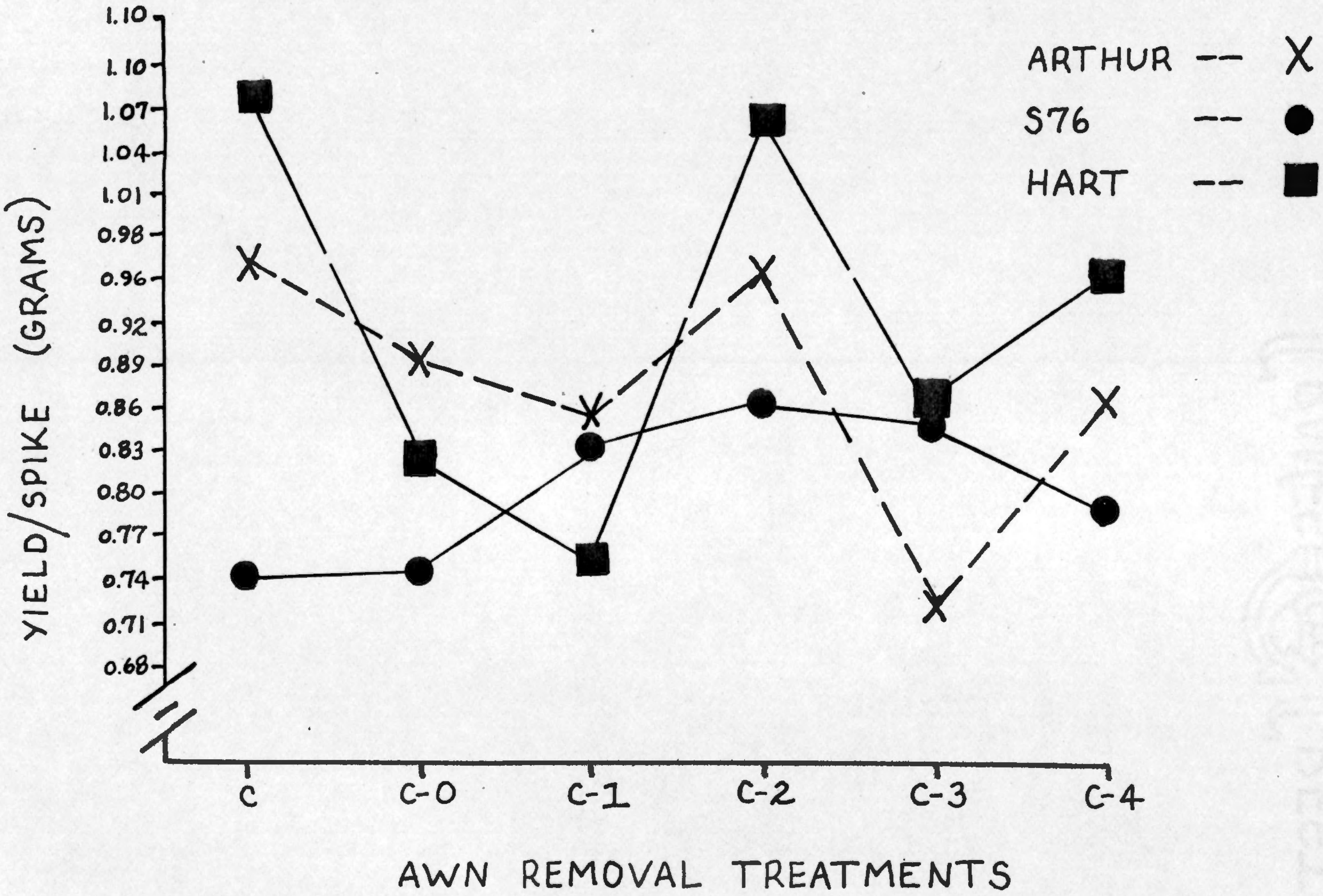

Figure 2. Mean Yield Per Spike of Awn Removal Treatments for Three Varieties of Soft Red Winter Wheat

Analysis of variance revealed significant variety X clipping interaction for yield per sample, yield per spike, and hundred kernel weight. Different variety response patterns were revealed in yield per sample when all awn removal treatments were considered (Figure 1). However, DMRT showed significant differences among the varieties only in treatment C. In this treatment Hart (77.15 g) was significantly greater ($P \leq .05$) than S76 (51.27 g), but Arthur was not different from either of these (Table 3). Different variety response patterns were also found in yield per spike when all treatments were considered (Figure 2). Again DMRT indicated significant differences among the varieties only in treatment C. In this treatment Hart (1.07 g) was significantly greater ($P \leq .05$) than S76 (.74 g), but Arthur was not different from either of these (Table 3, page 19). Although Figures 1 and 2 reveal different patterns of response for the three varieties, the results of DMRT indicate that all lines pass through the same point in each respective treatment except for C. The significant variety X clipping interaction for yield per sample and yield per spike is due to the significant varietal differences in the control treatment (C) and the lack of varietal differences in the awn removal treatments.

Different variety response patterns were revealed in hundred kernel weight when all treatments were considered (Figure 3). The DMRT showed significant differences among varieties at C, C-0, C-2, C-3, and C-4. In treatment C Hart (3.63 g) was significantly greater ($P \leq .05$) than S76 (Table 4). In the C-0 treatment Arthur (3.47 g) had the highest mean hundred kernel weight and Hart had the next highest. Both were significantly greater ($P \leq .05$) than S76. There were no

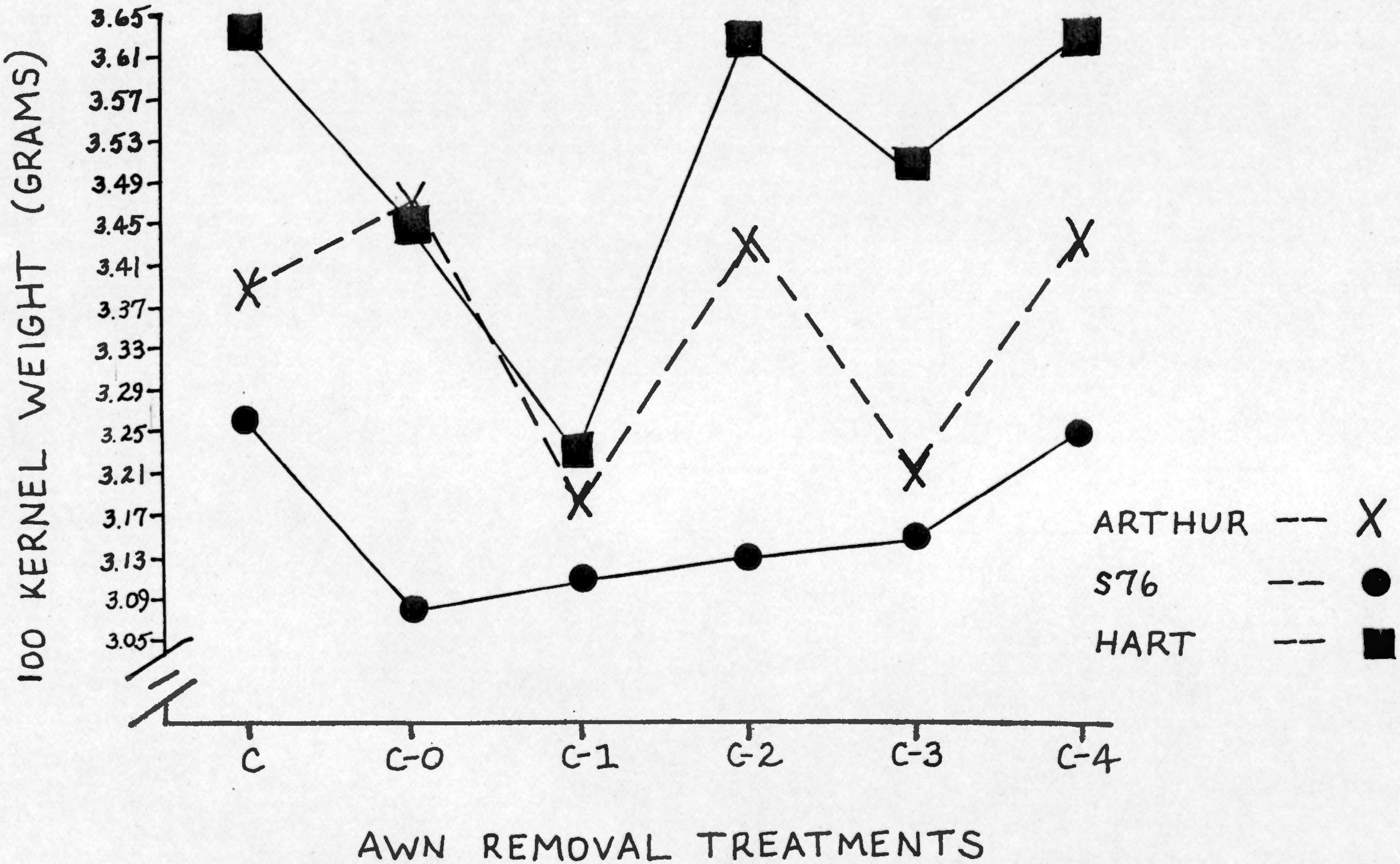

Figure 3. Mean Hundred Kernel Weight of Awn Removal Treatments for Three Varieties of Soft Red Winter Wheat

variety differences in C-1. In C-2 Hart and Arthur were significantly greater ($P \leq .05$) than S76; 3.62 and 3.43 versus 3.13 g, respectively. In C-3 and C-4 Hart was significantly greater ($P \leq .05$) than S76, but Arthur was not different from either Hart or S76 in both treatments. It is evident from Figure 3 that Hart and Arthur were affected more by the awn removal treatments than was S76.

CHAPTER V

SUMMARY AND CONCLUSIONS

These studies on soft red winter wheat showed that there were differences in grain yield and various yield components due to the removal of awns.

The removal of awns had no significant effect on yield per sample in the tip awned variety Arthur. Significant differences did occur in yield per spike in Arthur. However, the author believes that the unusually low number of kernels per spike in C-3 possibly biased this treatment response. There were no differences in Arthur for the components kernels per spike, test weight, and hundred kernel weight.

The removal of awns had a significant effect on the yield of the fully awned variety S76. However, it was not understood if the significant differences were due to the awn removal effects or the occurrence of rainfall coinciding with C-2. One yield variable which did bias the C-2 effect on yield was spikes per sample. Especially in S76, there was a higher number of spikes per sample in C-2 than in other awn removal treatments. If the C-2 effect was eliminated, there would be no differences in yield due to awn removal treatments. The author believes there was an environmental influence superimposed on C-2 and another year of data would probably eliminate this bias. There were no differences in yield per spike, kernels per spike, hundred kernel weight, and test weight in S76.

Significant differences in yield per sample and yield per spike due to awn removal occurred in Hart, another fully awned variety. The yield pattern shown by Hart closely matched the results published by other workers (9, 14, 17, 20) except for the C-2 effect. That is, the earlier the awns were removed, the greater the yield was reduced. Significant differences in hundred kernel weight also occurred in Hart. C-1 resulted in the lowest kernel weight among the various treatments. There were no differences in kernels per spike and test weight in Hart.

Since all three varieties had high yields accompanying C-2, it was speculated that an environmental factor induced the respective yield increases. The yield affecting factor which was suspected was the substantial rainfall.

It appears from this study that removal of tip awns in Arthur does not significantly affect grain yield. However, the conclusions that can be formulated concerning the influence of full awns on grain yield are contradictory since Hart and S76 yielded conflicting data. Removal of awns in Hart seemed to decrease yield, while removal in S76 caused nonsignificant variation in yield.

CHAPTER VI

FURTHER RESEARCH

Environmental factors such as rainfall and amount of sunlight need to be studied to determine the effect of awn X environment interaction on yield of soft red winter wheat.

The author believes that removal of awns may cause a metabolic shock such that yield reductions in plants may not be due to reduced photosynthetic area but the disorder associated with awn removal. To circumvent such a problem, isogenic lines should be developed and studied under different moisture conditions. Previous reports indicate that the presence and length of awns are determined by two genes in most instances. A series of backcrosses could be utilized to gain the desired isogenic lines.

Another area where study should be conducted is in the effect of awns on biochemical products of yield. More information is needed about the specific synthesis sites of certain amino acids such as lysine. Utilization of labeled CO_2 has been and probably will continue to play an important role in this area of research. It would be quite enlightening to determine the relative amino acid amounts present in the grain in awned versus awnless wheat types.

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VITA

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