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Title: EFFECT OF PRECIPITATION VARIATION AND FERTILIZATION LEVEL ON THE NUTRITIVE VALUE OF WHEAT RESIDUE

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Abstract Approved: ______________________

Dr. Martin Vavra

Five simulated precipitation patterns characteristic of the Columbia Basin and Plateau region and six fertilization rates were evaluated for their effect on percent crude protein, percent *in vitro* dry matter digestibility, fiber content, and yield of wheat aftermath on a commercial farm in north central Oregon.

The higher moisture regimes showed the greatest increase in percent crude protein with increasing nitrogen fertilizer levels. Chaff and straw values were significantly higher for the dry fallow-normal crop precipitation pattern than for normal fallow-dry crop pattern and significantly higher for the wet fallow-normal crop pattern than for normal fallow-wet crop.

Percent *in vitro* dry matter digestibility also increased under the high moisture precipitation patterns and there was a positive relationship between fertilization level and digestibility. The digestibility values for chaff and straw were higher for the dry fallow-normal crop precipitation regime over the normal fallow-dry crop only at the higher

fertilization levels. Examination of wet fallow-normal crop vs. normal fallow-wet crop showed increased digestibility for the pattern receiving more moisture in the fallow period, also at only the higher fertilization levels.

This study indicated that higher moisture regimes resulted in increased straw and chaff yields. Although not significant for every precipitation pattern, there was indication of a positive relationship between fertilization level and straw and chaff yields. For both straw and chaff yield, no difference was seen when comparing dry fallow-normal crop and normal fallow-dry crop regimes. Testing wet fallow-normal crop vs. normal fallow-wet crop patterns revealed increased chaff yields at higher fertilization levels under the pattern receiving less moisture in the fallow period, but increased straw yields at higher fertilization levels under the pattern receiving more moisture in the fallow period.

Percentages of acid detergent fiber, lignin, and cellulose were not significantly affected by precipitation variation or level of fertilization. The fertilization by precipitation pattern interaction was not a significant source of variation, with the exception of percentage crude protein of wheat straw in the first year.

The Effect of Precipitation Variation and Fertilization Level on the Nutritive Value of Wheat Residue

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INTRODUCTION

As the world population-food situation becomes more acute, man and animals will compete more for feed grains. Beef cattle will have to depend more on products that humans cannot digest or will not eat, such as crop residues that would otherwise be wasted. Klopfenstein (1975) has suggested there is approximately a 1:1 ratio, by weight, of collectible residue to grain produced, amounting to about 1.25 billion tons of residue produced worldwide each year. This cereal residue has several components. Plant stems left as stubble and then harvested are termed straw. Outside hulls, some grain (the amount varies with the efficiency of the combine) and a small quantity of broken straw and other foreign material left in the field behind the combine are called chaff. Collectively, the stubble, straw and chaff are designated cereal residue.

Research has demonstrated that beef cows can be successfully maintained on rations consisting primarily of crop residues, showing the compatability of crop and beef production. Daily nutrient requirements of a 500 kg. cow with average milking ability range from 14.1 to 19.2 Mcal of metabolizable energy (ME) and .42 to .90 kg of crude protein from mid-gestation to early lactation. Lactating cows with superior milking ability may require up to 24.3 Mcal of ME and 1.29 kg. of crude protein daily (N.R.C., 1976).

Crop residues, because of their relatively low availability of ME, are most efficiently utilized in maintenance rations for gestating cows when the energy requirement is less than during lactation. Along with crude protein, cereal residues may be deficient in certain minerals, particularly phosphorus, and very low in vitamin A, and it would be necessary to supplement these nutrients to prevent deficiencies.

The purpose of this study was to estimate the nutritive value and yield of wheat (<u>Triticum aestivum</u>) residue for grazing by domestic animals and to evaluate the effect of seasonal variation in precipitation and fertilizer nitrogen levels on nutrient variability. The specific objectives were: 1) to measure the influence of five simulated precipitation patterns and six fertilization rates on the percent crude protein, percent digestibility and fiber content of winter wheat residue, 2) to determine the yield of chaff, straw, and total (chaff + straw), and 3) to draw conclusions as to the influence of these treatments on the relative nutrient value of cereal crop residues as livestock feed.

LITERATURE REVIEW

Plant Growth and Development

During the course of growth and development of wheat, there is a general downward trend in nitrogen and dry weight in the leaves and culms (Knowles and Watkin, 1931; McNeal *et al*. 1968). Much of the assimilate taken up by grain is produced by the top leaves, especially by the flag leaf (Rawson and Evans, 1971). The assimilate is often translocated from the source to various parts before reaching the grain. The lower leaves and culms contribute only 5 to 10 percent of the assimilate to the grain, but are necessary in plant and root maintenance. Under various stress conditions, the lower leaves and culms may play a more important role in grain development.

Stage of Maturity

Relative proportions of plant nutrients change with maturity as the growing season progresses from the lush, green stage to the mature, seed-setting phase. Crude protein declines (Mellin *et al*. 1962; Heaney *et al*. 1966; Weir *et al*. 1960). Crude fiber increases and dry matter digestibility decreases (Murdock *et al*. 1961; Heaney *et al*. 1966; Staples *et al*. 1951). Pritchard and associates (1963) reported that *in vitro* dry matter digestibility of several forages decreased at the rate of approximately 0.5 percent per day. The decline in digestibility as the season progressed was observed in all portions of the plant, the rate of decline for heads and stems being greater than for the leaves.

Van Soest (1967) showed that cell-wall constituents of plant materials are composed essentially of hemicellulose, cellulose, and lignin. Lignin increased steadily during the growing period (Meyer *et al*. 1957; Ferebee *et al*. 1972). In a study conducted by Crampton and Maynard (1938), data supported the generalized opinion that dietary lignin is not appreciably metabolized by animals. Kamstra *et al*. (1958), Dehority *et al*. (1962), and Van Soest (1964) demonstrated a negative correlation between forage lignin and/or cellulose and dry matter digestibility. Lignin and cellulose occur in plants chiefly as a ligno-cellulose complex (Crampton and Maynard, 1938). Dehority and Johnson (1961) showed that lignin acts as a physical barrier between cellulose and rumen bacteria. Gray (1947) determined that lignin was indigestible. Cereal residue lignin was relatively high for wheat straw (McAnally, 1942; Coombe and Preston, 1969; Mulholland *et al*. 1974). The average value for cereal straws was two to three times the quantity Van Soest (1973) reported for grasses. Pigden (1953) showed plant lignin increases were due to changes in the proportion of plant parts and to the increase in lignin within each plant part. Also, as cereals ripen, many of the most easily digested nutrients are translocated from the stems and leaves to the seeds and after harvest only the more fibrous, structural material remains.

Plant Parts

Leaves and culms have been shown to differ in protein content. Mowat *et al*. (1965) studied the protein content of the stems and leaves of timothy (*Phleum pratense*), orchardgrass (*Dactylis glomerata*), and bromegrass (*Bromus inermis*) at progressive sampling dates. At all growth stages, leaves had a higher protein content. Stems, even at the earliest growth stages, never had more than 10.4 percent crude protein. Leaves averaged 13 to 14 percent crude protein and bromegrass leaves had up to 17 percent. Late in the season leaf crude protein, averaged across species, was about 8 percent and culm protein was only about 4 percent.

Kilcher and Troelson (1973a) also reported higher crude protein levels in leaves but the difference was not as pronounced late in the season. Oat (*Avena sativa*) leaves contained about 20 percent crude protein mid-way through the growing season while culms averaged 10 percent. At maturity, leaf and culm protein levels were 6 and 5 percent, respectively.

Leaves also appear to be more digestible than stems. Kilcher (1975) reported that leaf and culm organic matter digestibility was approximately 70 and 55 percent, respectively, early in the growing season. At the end of the growing season (October), the respective values were about 50 and 40 percent.

Mowat and associates (1965) also examined leaf and stem digestibility. However, at early growth stages, culm digestibility was actually greater than leaves for timothy, orchardgrass, and bromegrass. Average culm and leaf digestibility values early in May were about 80 and 75 percent, respectively. Culm digestibility decreased at a more rapid rate than leaf digestibility. By mid-July, leaf digestibility was about 55 percent while culm digestibility was only about 48 percent. Terry and Tilley (1964) and Kilcher and Troelson (1973b) also reported greater digestibility in leaves compared to culms.

Moisture Stress

It is possible that factors which interfere with or promote the translocation and assimilation processes not only affect grain production and quality, but also that of the cereal residue. Various metabolic changes occur when a plant is stressed. There is a conversion of starch to sugars, contributing to an overall increase in sugar content (Smith, 1966; Lamm, 1976). Furthermore, it has also been suggested that moisture stress may decrease growth, but not affect photosynthesis. Factors such as heat or drought, which inhibit cell metabolism, can slow or stop assimilate movement through the cells (Salisbury and Ross, 1969). The conditions which might exist under moisture or heat stress are: 1) impaired translocation of assimilates, 2) continued photosynthesis, and 3) conversion of starches to sugars. This would improve residue quality, decrease yields, and negatively affect grain weight and production.

There have been numerous field and greenhouse studies evaluating the effects of moisture levels on cereal growth and production. Fedack and Mack (1977) seeded two barley cultivars and maintained them at three moisture levels (25, 50 or normal rainfall, and 90 percent capacity). They found a positive correlation between moisture and straw yields for both varieties. For example, 3587 kg straw/hectare was produced under a low moisture regime, but with 90 percent field capacity production was 5179 kg/ha.

Aspinall and co-workers (1964) studied the effects of long and short cycles of water stress on tillering and stem elongation of barley. Depending on the timing and number of cycles, water stress was responsible for both increased and decreased tillering. More than one short cycle of water stress suppressed tillering. When only one short cycle was applied, however, tillering was increased. Plants stressed late in development produced the longest culms. The authors felt this may have been due to the suppression of short tillers which are normally produced late in the growth cycle, thereby increasing the overall mean tiller length. These conclusions correspond to the hypothesis that soil moisture stress affects those processes in the plant parts growing fastest at the time of stress. Campbell (1968) felt the phenological stage at which stress was applied was not as significant as total water used. Thus, the more water available, the greater the yield. His results were still in agreement with Aspinall _et al_. (1964) since their results showed an increase in yield with increasing moisture. Day and Thompson (1975) found water stress decreased plant height in general, but that it promoted tillering when applied at the jointing stage.

Spratt and Gasser (1970) reported drought during tillering resulted in smaller leaves and shorter, thinner stems. However, when it occurred during stem extension or heading, there was little effect on leaf, stem, or chaff yield. Campbell _et al_. (1977) found a decrease in tillering with a general decrease in soil moisture. Campbell _et al_. (1969) also noted a negative correlation between water stress and tillering.

Excess water has also been shown to be detrimental to straw production. Watkins _et al_. (1976) noted that both intermittant and continuous water-logging reduced straw yields as the result of decreased tillering. The continuous treatment affected the yields more severely.

Moisture levels also affect straw nitrogen content. In the work of Fedack and Mack (1977), the effects of moisture levels on straw protein were significant, but the relationship was not as clear as were yield responses. There was a general inverse relationship between moisture levels and straw protein. With later planting dates, grain yield and grain protein content decreased with decreasing moisture. This indicates reduced translocation of nitrogen and carbohydrates from the stems and leaves to the grain. Aspinall (1965) also noted water stress hindered movement of assimilate from the leaves to the ear.

Nitrogen Fertilization

In studies on the control of protein content of wheat by application of a nitrogen fertilizer, Hutcheon and Paul (1966) found that high levels of nitrogen had more influence on the growth of straw than grain; the straw:grain ratio widened with increasing increments of nitrogen. These results correspond with the work of Spratt and Gasser (1970), Dougherty (1973), and Field and Engle (1975). In 1963, Rohde determined that nitrogen fertilization was responsible for increases in grain yield, number of culms per plot, plant height, and straw weight in all varieties of wheat tested.

The efficiency of nitrogen fertilization can vary considerably with the available moisture. Humbert and McVickar (1963) reported a significant positive correlation between available moisture in the soil at seeding time with both grain and straw yields of winter wheat at different levels of nitrogen fertilization. Increased yields were seen with each increment of nitrogen added at the higher levels of available moisture. These results differed from those of Campbell et al. (1977), which showed an increase in both grain crude protein content and yield with increased nitrogen applications but no effect on straw yield.

Cereal Residues as a Feed Source: General Quality

Cereal residue is considered, at best, a low quality feed. It is usually deficient in crude protein, carotene, and phosphorus. Additionally, it can contain a high proportion of lignin and silica which reduce the digestibility of available nutrients. Schultz and French (1976) reported a range of 1.0 to 7.2 percent crude protein for straw and 2.62 to 8.44 percent crude protein for glumes. Average phosphorus values for straw and glumes were 0.05 and 0.1 percent, respectively. Kay et al. (1970a) reported 1.4 to 6.7 percent protein for wheat stubble. Wheat chaff contained 3.1 percent protein. These values agree with those given by the N.A.S. (1971) for wheat straw.

Intake and Digestibility

Van Soest (1965) reported that as forage cell-wall constituents increased above 50 percent of dry matter, voluntary intake declined. Intake was highly correlated with chemical composition and digestible dry matter in forages with a high cell wall content. Coombe and Tribe (1963) found voluntary intake was positively correlated with rate of passage. Greenhalgh and Reid (1967) and Blaxter et al. (1961) also showed a positive correlation between intake and digestibility.

Campling et al. (1961) found that a low intake of long straw, relative to hay, was due to lower digestibility and a longer reaction time. Blaxter and Wilson (1962) reported that ad libitum intake of oat straw was 43 percent below hay due to the less apparent digestibility of energy. Low protein and high cell wall and lignin contents of cereal residues have important implications when nutritive value is defined as the product of consumption and digestibility.

Processing

Burt (1966) suggested that grinding and pelleting barley straw converted it from an unpalatable material incapable of supporting maintenance into one capable of use as a major constituent in highly productive diets. Joyce (1966) found voluntary intake of ground, pelleted oat straw by cows was 26 percent greater than for long straw. However, digestibility of ground material was lower than for the long form. Grinding reduced the particle size and increased the rate of passage, leaving less time for reticulo-rumen fermentation. However, Minson (1963) showed an increased gross feed efficiency because greater intake produced greater gain. When ground or pelleted barley straw replaced corn (at levels of up to 50 percent) in concentrate diets fed to Holstein calves, dry matter intake was positively related to the proportion of straw (Lamming et al. 1966; Pickard et al. 1969). When diets containing ground straw and concentrates were offered to young steers, increasing amounts of dry matter were consumed as the proportion of straw increased (Kay et al. 1970b). All of these responses are likely due to the favorable effects that fiber has on rumen function, especially in a high concentrate ration. Also, the cell wall constituent level would be below the intake limiting point. Dry matter digestibility decreased as the levels of straw increased in each of these trials. Raven et al. (1969) showed that organic matter digestibility fell sharply as straw replaced concentrates. Levy et al. (1972) pelleted a ration containing 15 to 30 percent wheat straw and found feed intake and organic matter digestibility were greatest on the former. Bines and Davey (1970) reported that chopped barley straw incorporated into pelleted concentrate diets had no effect on dry matter intakes. Research by Burt (1966) showed that when 2.5 kg. of pelleted straw was substituted for slightly less long straw, gain was increased 80 percent due to reduced time to consume the food and reduced energy expenditure of chewing and ruminating. Beardsley (1964) concluded that grinding and pelleting increased feed intake by 25 percent, daily gain by 100 percent, and feed efficiency by 35 percent. The dry matter intake of oat straw was 53 and 33 percent higher than for wheat straw and barley straw because of higher digestibility (Mulholland et al. 1974). These results agree with data of Coombe and Tribe (1963), Hemsley (1964), Oh et al. (1971) and McManus et al. (1972).

Chemical Treatment

Numerous chemicals have been studied for the potential to enhance digestibility of cereal residues. However, only four compounds are being routinely used in experimentation with animals. These are sodium hydroxide (Anderson and Ralston, 1973; Garrett et al. 1976; Klopfenstein and Koers, 1973; Rounds and Klopfenstein, 1974) which is used in the greatest guantity, ammonium hydroxide (Garrett *et al*. 1976; Waiss *et al*. 1972; Waller and Klopfenstein, 1975), calcium hydroxide (Rounds and Klopfenstein, 1974; Waller and Klopfenstein, 1975) and potassium hydroxide (Klopfenstein and Woods, 1970; Rounds and Klopfenstein, 1974).

Modes of action of chemical treatment have been described by Waller (1976). Chemical treatment solubilizes some of the hemicellulose while not changing the cellulose content. Extent of bacterial digestion *in vitro* is increased for both cellulose and hemicellulose, and sodium hydroxide appears much more effective than either calcium or ammonium hydroxide. With regard to the rate of cellulose and hemicellulose digestion, chemical treatment especially with sodium hydroxide was responsible for a significant increase. It is logical to conclude that the methods of action of chemical treatment, particularly with sodium hydroxide, include: 1) solubilization of hemicellulose, 2) increasing the extent of cellulose and hemicellulose digestion, and 3) increasing the rate of cellulose and hemicellulose digestion (Tarkow and Feist, 1968). Lignin content is generally not reduced by chemical treatment (Klopfenstein *et al*., 1972; Rexen and Thomsen, 1976), so the increase in digestibility is probably due to breaking the bonds between lignin and hemicellulose or cellulose without the actual removal of lignin. Several studies have shown that residues from different plant species respond differently to chemical treatment (Chandra and Jackson, 1971; Rexen and Thomsen, 1976).

Data relating to the level of chemical, especially of sodium hydroxide, used in treatment of residues suggest two important points. First, the level of treatment for optimum response in the animal ranges from 3 to 5 percent of residue dry matter. Second, there is a difference in response to chemical treatment as measured by *in vitro* and *in vivo* results. Rexen and Thomsen (1976) showed that increases in the digestibility of barley straws were consistent between *in vitro* and *in vivo* results with the addition of up to 4 percent sodium hydroxide. With higher levels, the *in vivo* digestibility did not increase while digestibility *in vitro* appeared to increase. Klopfenstein and associates (1972) also showed that *in vitro* dry matter digestibility of corn stover increased with 3 percent sodium hydroxide treatment, and a further increase was obtained with 5 percent treatment. When corn stover was fed as the only roughage in the diet *in vivo* digestibility did not increase at the 5 percent level of treatment over that obtained at the 3 percent level.

Supplementation

The ability of ruminants to utilize roughages depends on rumen microbial activity, which requires an adequate nutrient supply. Cereal residues have inadequate nitrogen to satisfy microbial growth requirements (Burroughs *et al*. 1950c; Shrewsbury *et al*. 1942). Maximum digestibility and intake depends on supplementation. Alfalfa hay, high protein feeds, and cereal grains had favorable influences on digestibility of poor quality roughages (Burroughs and Gerlaugh, 1949; Burroughs *et al*. 1949a, 1950a, 1950d). Lyons and co-workers (1970) reported an increase in the crude protein content of a supplement increased the digestibility of crude fiber and protein. A low protein, high energy, combination of supplements was frequently refused and cattle gains were low (Andrews et al. 1972). While low levels (up to 25 percent) of concentrates increased the intake of low quality roughages, high levels produced a substitution effect where roughage intake decreased as the level of concentrate increased (Crabtree and Williams, 1971).

Responses to supplementation with urea have been variable. Coombe and Tribe (1960) showed that urea increased oat straw digestion rate and level of digestibility, and reduced retention time. Coombe and Tribe (1962), Hemsley and Moir (1963), Weston (1967), and Faichney (1968) showed that urea promoted faster passage rates and increased straw intakes and gains. Campling and Freer (1966) found that a daily intraruminal infusion of urea increased voluntary intake of ground pelleted oat straw by 53 percent. Campling et al. (1962) reported a 40 percent increase in a similar study. Organic matter digestibility was increased from 41 to 50 percent.

Not all responses agree with these data. When straw was enriched with barley meal, urea failed to increase passage rate or intake (Sharma et al. 1972a). In another study, it reduced retention time, increased intake 17.2 percent, and reduced weight losses (Sharma et al. 1972b). The addition of molasses to these diets reduced protein and fiber digestibility, passage rate, and straw intake. Straw intake by steers and pregnant heifers was increased 20 percent with the addition of urea-containing molasses sugar beet pulp cubes (Fishwick et al. 1973). While Coombe and Tribe (1960, 1963) have reported increases in voluntary intake when urea was added to a straw and molasses diet, Hemsley and Moir (1963) showed that urea markedly increased milled oat hay intake but molasses made no further improvement. Joyce (1975) reported that a weight loss from a barley straw diet was reduced by adding barley or corn, but urea had no effect. Kay _et al_. (1968) found neither intake nor digestibility was improved by the addition of urea or barley. However, this barley straw contained 5 to 7 percent crude protein. Coombe and Tribe (1962) suggested that response to nitrogen and energy supplements was dependent on the crude protein content of the roughage.

Where the energy substrate was obtained from a fibrous source, supplementation with urea resulted in poor utilization and low productivity (Coombe _et al_. 1971). Maximum intakes of cereal residues occurred when small amounts of starch-type carbohydrates were fed in addition to urea (Crabtree and Williams, 1971; Fishwick _et al_. 1973; Andrews _et al_. 1972). Up to 10 percent starch had little effect on cellulose digestibility, but 30 percent depressed it severely (Mulholland _et al_. 1976). Roughage digestibility depressions were also reported by Burroughs _et al_. (1946b) and Kane _et al_. (1959). When urea and sucrose were infused together, sucrose was used in preference to straw and depressed straw intake and dry matter digestibility (Winter and Pigden, 1971). Faichney (1965) showed that the addition of sucrose to urea supplemented straw rations did not affect the intake and utilization of the diets. Campling _et al_. (1961) and Hemsley and Moir (1963) concluded that lack of a supplement of readily available energy was not a limiting factor in the utilization of oat straw.

Hay intake was increased when a volatile fatty acid mixture (isobutyric, n-valeric and isovaleric) was added, because of direct stimulation of microbial growth (Hemsley and Moir, 1963). Bentley and associates (1955) and Hungate and Dyer (1956) identified five and six carbon branched or short chained fatty acids as nutrient requirements of cellulolytic bacteria. Falen et al. (1968) found that urea plus volatile fatty acids increased straw intake but to no greater level than urea alone.

Mulholland and co-workers (1976) have suggested that the variation in response to the addition of urea to low quality roughages might be due to variation in mineral content among roughages. Burroughs et al. (1950a, b, c) had established that roughage digestion could be improved by mineral supplementation. Kane et al. (1959) reported that in vitro cellulose digestibility and urea utilization were increased when sulfur was added. Sulfur supplements have also been shown to increase gains (Starks et al. 1954). A supplement of urea and sulfur increased dry matter intake 115 percent partially due to increased microbial synthesis (Faichney, 1968). Kennedy and Siebert (1972) supported this result. Coombe and Christian (1969) suggested that phosphorus supplementation improved urea utilization, although this could not be documented by Fishwick et al. (1974) or Coombe et al. (1971).

Performance

Several studies have substituted chopped, ground, and/or pelleted cereal straws for cereal grains. Lamming et al. (1966) found that Holstein steers fed diets containing up to 30 percent barley straw substituted for corn made similar gains. Rate of gain was reduced by the inclusion of 50 percent straw. Swan and Lamming (1967) have confirmed this growth response and also showed that the major carcass effect was a decrease in fat deposition. There were no differences in performance due to particle size (Pickard et al. 1969). When the level of straw was raised to 70 percent, the dressing percentage declined due to an increase in digestive tract contents (Swan and Lamming, 1970). Forbes et al. (1969a, b) and Kay et al. (1970a, b) also showed that as the percentage dietary straw increased, dressing percentage declined.

When Forbes and co-workers (1969a, b) compared coarsely chopped barley straw at 0, 20, and 40 percent of a concentrate diet, there was a decrease in gain of .95 kg per level of increase in straw. Thirty percent straw in all concentrate diets was also associated with lower rates of gain and higher feed conversion ratios (Raven et al. 1969). Kay et al. (1970a, b) found that replacement of cereals with 5, 20, 35, and 50 percent chopped or ground barley straw caused a decline in gain of young steers as the proportion of straw increased and the energy intake decreased. The differences observed among these trials likely can be attributed to differences in particle size, ration form, kind of basal gain and animal age. When steers were fed complete pelleted diets containing 40, 55, and 70 percent barley straw, daily gains were .81, .71, and .66 kg, respectively, while feed conversions were 10.9, 12.0, and 14.1 kg feed per kg of gain (Weisenburger and Mathison, 1976). In all these studies, varying levels of straw replaced cereal grains without keeping caloric intake equal. Therefore, at the lower straw levels, energy intake and gain would be higher. Wheat straw compared favorably with cottonseed hulls as a roughage source in finishing rations when included at the 15 percent level (Frahm et al. 1971).

Controlled experiments using cereal residues in maintaining beef cows are limited. Sharma and associates (1972b) compared cottonseed hulls, milo stover, and wheat straw (sliced and water added) as roughage sources for dry pregnant cows. All cows gained .23 kg per day and calf birth weights and vigor were not significantly different. The level of consumption of wet, sliced wheat straw was greater than for long, wheat straw. However, untreated wheat straw was not equal to cottonseed hulls when incorporated with alfalfa hay for lactating cows (Sharma _et al_. 1972a). Cow and calf gains and milk production were lower for the straw supplemented cows.

MATERIALS AND METHODS

The study was conducted from July 1979 to August 1980. The study area was located in Sherman County, in north central Oregon. Three major rivers, the Columbia, the Deschutes, and the John Day, border the county on the north, west, and east sides respectively. Precipitation falls predominantly during the months of October through March. Average yearly precipitation is 299 mm.

Five fallow-crop precipitation patterns representative of the 250-350 mm precipitation zone of the Columbia Basin and Plateau were simulated on a commercial farm near Moro, Oregon. The natural precipitation received during this period was considered as a control treatment. In the crop year 1978-1979, 218 mm, and 1979-1980, 407 mm of precipitation fell (Table 1). Plastic tarps on PVC support grids were rolled over the plots during periods of rainfall to exclude precipitation in the fallow or crop season. Moisture was applied to the crop using a solid set irrigation system, and was regulated on a monthly basis. The crop was planted in late September of 1978 and 1979, and all tillage operations were carried out by the farmer as part of his normal operation.

Cereal residues collected consisted of the standing stubble and chaff of Stephens winter wheat harvested in the summers of 1979 and 1980. Collection consisted of clipping the stand to a height of 5.08 cm above ground level from 4.8 m of row in each subplot. Crop residue material was manually separated into grain, chaff and stems. The straw and chaff samples were ground through a 5 mm screen.

Table 1. MONTHLY PRECIPITATION (mm) FOR CROP YEARS 1978 THROUGH 1980 AND A THIRTY YEAR AVERAGE AT THE MORO EXPERIMENT STATION IN MORO, OREGON

	30 year average	1978-1979	1979-1980
September	12.7	8.4	13.5
October	25.4	0.3	65.8
November	45.7	20.1	56.6
December	43.9	17.5	16.5
January	45.2	40.4	86.6
February	29.7	39.1	48.5
March	24.1	25.2	23.9
April	18.3	26.9	21.6
May	21.8	7.1	32.3
June	20.1	2.5	34.8
July	5.1	1.8	4.1
August	6.7	28.5	2.8
Total	298.7	217.8	407.0

Cereal residues were analyzed for percent crude protein by the Kjeldahl distillation procedure (A.O.A.C., 1976). Dry matter digestibility was determined by the two-stage *in vitro* analysis as described by Tilley and Terry (1963). Acid detergent fiber and lignin were determined according to the procedure described by Goering and Van Soest (1970) and percent cellulose was calculated from these analyses.

The experimental design was a split-plot with four blocks. The precipitation patterns were the main plots; they consisted of dry fallow-normal crop (DFNC), normal fallow-dry crop (NFDC), normal fallow-normal crop (NFNC), wet fallow-normal crop (WFNC), and normal fallow-wet crop (NFWC). These combinations are representative of systems most likely to occur in the region (Figure 1). Nitrogen fertilizer (32% N) applied at six levels (0, 15, 45, 60, 75, 105 kg N/ha) constituted the subplots (Figure 2). In the 1979-1980 crop year, the NFWC pattern was duplicated. One pattern (NFWC-1) received its fertilizer allotment in a single fall application, as was the normal procedure for all other patterns. NFWC-2 received split applications of fertilizer, one-half the allotted amount in fall and the remainder in spring. The effects of precipitation variation and level of fertilization were analyzed with a least-squares analysis of variance and specific treatment mean comparisons were tested with the least significant difference (Steel and Torrie, 1960).

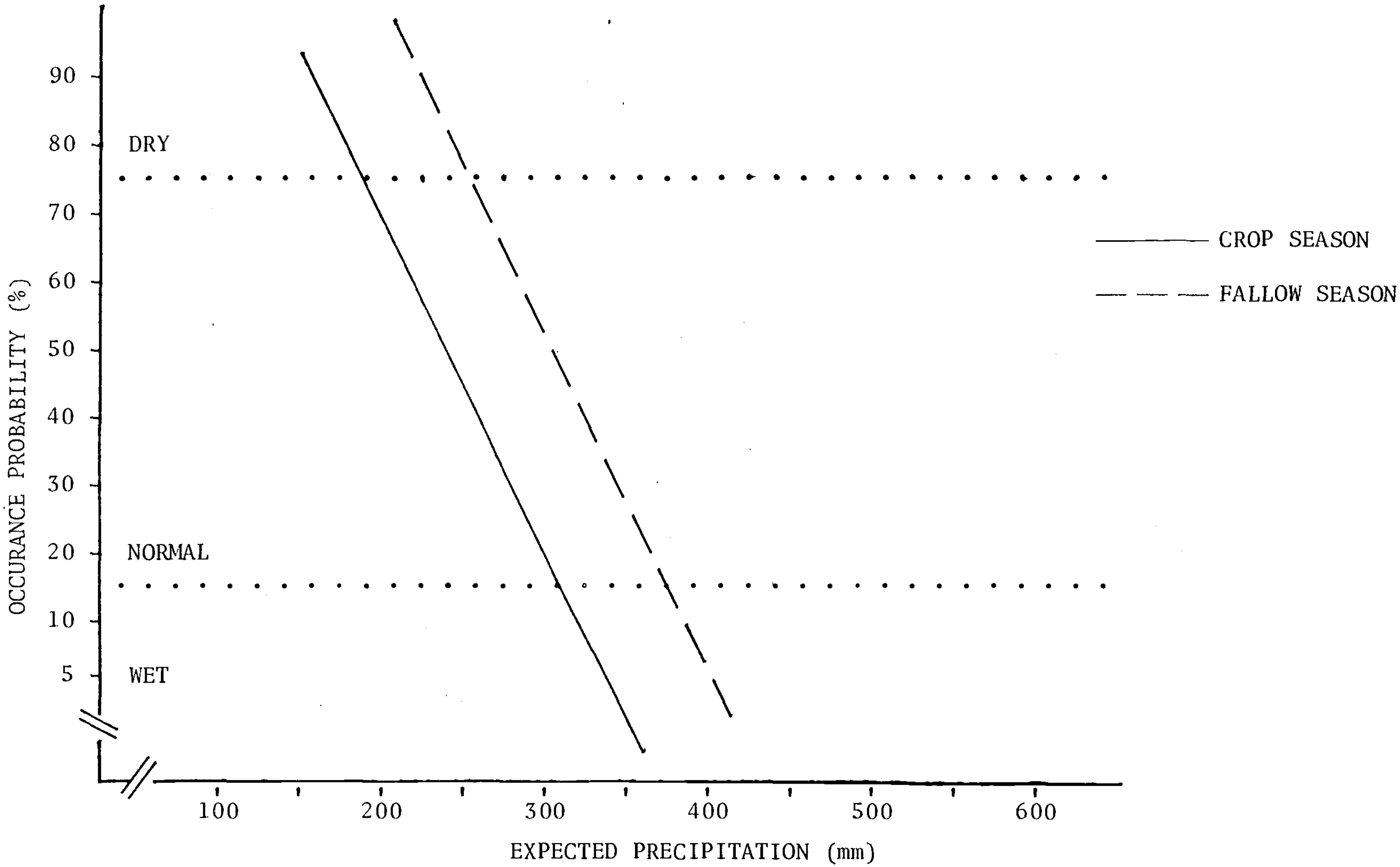

Figure 1. Expected precipitation levels, Moro, Oregon

1980

243165 F	432165 D	631425 A	365412 G	254613 B	431265 E	143526 C
312645 E	632145 G	124635 C	512643 D	231645 A	124365 F	642351 B
543162 G	432615 E	156423 B	365142 C	526143 D	426513 F	612354 A
315462 F	625413 B	621435 C	342165 D	321465 E	631542 A	415236 G

1979

246351 A		135624 B	214563 G	154362 C		431256 D	214563 F
421356 F		425631 D		436512 B	124635 G	451326 A	514362 C
431256 B	412635 G	132654 A		124563 C		624351 F	341265 D
134526 C		153426 D		631542 A	352146 G	126354 B	261345 F

A: DF NC
B: NF DC
C: NF NC
D: NF WC
E: NF WC (1980 only)
F: WF NC
G: CONTROL

1: 0 kg N/ha
2: 15 kg N/ha
3: 45 kg N/ha
4: 60 kg N/ha
5: 75 kg N/ha
6: 105 kg N/ha

Figure 2. Experimental design of residue study

RESULTS

In 1980, unseasonably cool and moist conditions prevailed from the heading through ripening stages. These conditions, in conjunction with a high level of crop season precipitation and errors in experimental management, masked treatment differences. For these reasons, interpretation of results for the crop years 1978-1979 and 1979-1980 will be discussed separately.

1978-1979 Crop Year

Chaff yield was significantly affected by both precipitation ($P < .05$) and level of fertilization ($P < .01$). For a given level of total precipitation, a comparison of the DFNC and NFDC patterns (Table 2) indicated no difference in chaff yield at the given levels of fertilization with the exception of 60 kg/ha. However, analysis of the WFNC and NFWC patterns (Table 3) showed a trend of increased chaff yields at the higher fertilization levels for the pattern receiving less moisture during the fallow period. This agrees with the work of Glenn (1981), who observed significantly higher grain yields in the NFWC pattern as compared with WFNC. Winter killing, which occured more on the WFNC treatment than on the normal or dry fallow treatments, reduced the number of tillers and vegetative material. Chaff yields of the NFNC regime (Table 4) were consistently lower than for all other precipitation patterns at every fertilization level excepting 0 kg/ha.

No difference was seen in straw yield for DFNC vs. NFDC at any level of fertilization excepting 45 kg/ha (Table 5). Straw yields were

Table 2. Yield of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
DFNC	306	180	145.75[a]	153.25[a]	165.25[a]	153.00[a]	165.75[a]	185.25[a]
NFDC	371	133	134.25[a]	147.00[a]	168.50[a]	183.00[b]	169.00[a]	185.00[a]

[a,b]Means in the same column with different superscripts differ (P < .05).

Table 3. Yield of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
WFNC	488	201	135.00[a]	163.50[a]	182.75[a]	168.25[a]	208.00[a]	191.25[a]
NFWC	371	290	135.75[a]	162.50[a]	198.75[b]	206.75[b]	193.25[b]	216.75[b]

[a,b]Means in the same column with different superscripts differ (P < .05).

Table 4. Yield of wheat chaff under a normal fallow-normal crop precipitation pattern for the crop year 1978-1979, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
NFNC	371	180	153.00	140.75	163.75	170.00	159.00	178.75

significantly greater at the 75 kg/ha fertilization level for the WFNC pattern, when contrasted with the NFWC precipitation pattern (Table 6). The precipitation treatments receiving more overall moisture had consistently higher straw yields than for the lower moisture groups, which agrees with the work of Campbell (1968) and Fedack and Mack (1977). NFNC straw yields (Table 7) were not different when compared to DFNC, while the NFDC pattern exhibited a significantly higher yield only at the 45 kg/ha fertilization level. NFNC yields were not significantly different from NFWC yields, and WFNC yields were significantly higher only at 15 and 75 kg/ha.

Percent crude protein of wheat chaff was significantly affected by both precipitation ($P < .05$) and level of fertilization ($P < .01$). Testing DFNC vs. NFDC indicated that the pattern receiving less moisture in the fallow period had significantly higher crude protein values at every level of fertilization (Table 8). Comparison of the higher moisture regimes disclosed an opposite trend, where the pattern receiving more moisture in the fallow period had higher crude protein values at each fertilization level excepting 105 kg/ha (Table 9). NFNC crude protein levels (Table 10) were significantly lower than for the DFNC pattern at every level of fertilization. Testing NFNC vs. NFDC showed NFDC pattern to have lower protein values only at 0 and 75 kg/ha but higher values at the 60 and 105 kg/ha levels of fertilization. Analysis of NFNC and WFNC revealed significantly lower crude protein values for WFNC only at 0 kg/ha fertilization level and higher values at the 60 and 105 kg/ha levels. The NFNC regime has significantly lower values for the crude protein at the 0, 15, and 75 kg/ha levels of fertilization

Table 5. Yield of wheat straw under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon (g./4.8 m subplot).

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg N/ha.) 0	15	45	60	75	105
DFNC	306	180	222.75^{a}	251.50^{a}	288.00^{a}	270.25^{a}	269.25^{a}	314.50^{a}
NFDC	371	133	234.75^{a}	249.75^{a}	367.00^{b}	328.75^{a}	290.50^{a}	312.40^{a}

^{a,b}Means in the same column with different superscripts differ ($P < .05$).

Table 6. Yield of wheat straw under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg N/ha.) 0	15	45	60	75	105
WFNC	488	201	250.25^{a}	304.75^{a}	344.25^{a}	327.75^{a}	414.75^{a}	350.25^{a}
NFWC	371	290	237.75^{a}	272.00^{a}	324.00^{a}	337.75^{a}	333.75^{b}	339.75^{a}

^{a,b}Means in the same column with different superscripts differ ($P < .05$)

Table 7. Yield of wheat straw under a normal fallow-normal crop precipitation pattern for the crop year 1978-1979, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg N/ha.) 0	15	45	60	75	105
NFNC	371	180	246.25	227.25	288.75	281.00	334.00	339.75

Table 8. Percent crude protein of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
DFNC	306	180	3.49[a]	3.42[a]	4.04[a]	3.95[a]	4.20[a]	4.22[a]
NFDC	371	133	2.70[b]	3.14[b]	3.37[b]	3.58[b]	3.45[b]	4.14[b]

[a,b]Means in the same column with different superscripts differ ($P < .05$).

Table 9. Percent crude protein of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
WFNC	488	201	2.73[a]	3.05[a]	3.38[a]	3.65[a]	3.61[a]	4.24[a]
NFWC	371	290	2.46[b]	2.52[b]	3.27[a]	3.44[b]	3.41[b]	4.33[a]

[a,b]Means in the same column with different superscripts differ ($P < .05$).

Table 10. Percent crude protein of wheat chaff under a normal fallow-normal crop precipitation pattern for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
NFNC	371	180	3.05	2.97	3.41	3.38	3.75	3.94

when tested against NFWC, but a higher value at the 105 kg/ha level.

As with chaff, crude protein values for wheat straw were significantly affected by precipitation ($P < .01$) and fertilization ($P < .01$). Crude protein values were significantly higher for DFNC than for NFDC (Table 11), and for WFNC vs. NFWC higher crude protein values were found under the regime receiving more moisture in the fallow period (Table 12). Testing of NFNC (Table 13) vs. DFNC straw crude protein values showed the DFNC pattern to be significantly higher at every level of fertilization excepting 105 kg/ha. NFNC vs. NFDC disclosed significantly lower protein values at 0, 45, and 105 kg/ha fertilization levels for the pattern receiving less total precipitation. When comparing WFNC and NFNC regimes, WFNC had significantly higher values at the two highest levels. Contrast of NFWC and NFNC demonstrated similar results; the NFWC pattern had lower values at all levels of fertilization excepting 75 kg/ha. Overall comparison of low and high moisture regimes showed a general inverse relationship between moisture levels and straw protein. This was perhaps due to reduced translocation of nitrogen and carbohydrates from the stems and leaves to the grain, and agrees with the findings of Aspinall (1965) and Fedack and Mack (1977).

The percent in vitro dry matter digestibility (IVDMD) of wheat chaff was significantly affected by both precipitation ($P < .05$) and level of fertilization ($P < .01$). Digestibility was significantly greater for DFNC than for NFDC only at the three highest levels of fertilization (Table 14). In reviewing WFNC vs. NFWC, a trend of increased digestibility ($P < .05$) with increasing levels of fertilization was seen for the WFNC pattern (Table 15). This pattern had higher

Table 11. Percent crude protein of wheat straw under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
DFNC	306	180	2.50[a]	2.61[a]	2.93[a]	2.84[a]	2.95[a]	2.93[a]
NFDC	371	133	1.85[b]	2.08[b]	2.25[b]	2.55[b]	2.52[b]	2.73[b]

[a,b]Means in the same column with different superscripts differ ($P < .05$).

Table 12. Percent crude protein of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
WFNC	488	201	1.85[a]	1.72[a]	2.27[a]	2.44[a]	2.70[a]	3.31[a]
NFWC	371	290	1.64[b]	1.85[a]	1.96[b]	2.33[a]	2.51[b]	2.68[b]

[a,b]Means in the same column with different superscripts differ ($P < .05$).

Table 13. Percent crude protein of wheat straw under a normal fallow-normal crop precipitation pattern for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
NFNC	371	180	2.20	2.17	2.75	2.58	2.56	3.03

Table 14. Percent *in vitro* dry matter digestibility of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
DFNC	306	180	45.56[a]	46.74[a]	50.32[a]	48.57[a]	53.63[a]	53.72[a]
NFDC	371	133	44.75[a]	45.39[a]	49.21[a]	50.87[b]	48.89[b]	50.85[b]

[a,b]Means in the same column with different superscripts differ (P < .05).

Table 15. Percent *in vitro* dry matter digestibility of wheat chaff under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
WFNC	488	201	45.28[a]	47.13[a]	49.66[a]	49.34[a]	51.27[a]	53.35[a]
NFWC	371	290	41.10[b]	43.32[b]	47.66[b]	50.26[a]	47.24[b]	54.32[a]

[a,b]Means in the same column with different superscripts differ (P < .05).

digestibility values than did the pattern receiving less moisture in the fallow period at all levels of fertilization with the exception of 105 kg/ha. Examination of NFNC (Table 16) vs. DFNC showed significantly higher IVDMD values for DFNC at the three highest fertilization levels, while comparing NFNC and NFDC revealed a higher value under the NFDC pattern only at the 60 kg/ha fertilization level. When comparing the NFNC pattern to the higher precipitation regimes, WFNC had significantly lower IVDMD values at the 0 kg/ha fertilization level, but significantly higher values at the 15, 60, 75, and 105 kg/ha levels. NFWC had signi-ficicantly lower values at the 0 and 15 kg/ha levels and significantly higher values at the 60 and 105 kg/ha levels.

Wheat straw dry matter digestibility was significantly affected by both precipitation ($P < .01$) and fertilization level ($P < .01$). A trend towards increased digestibility with increased level of fertilization was seen, and DFNC vs. NFDC revealed significantly higher IVDMD values for the DFNC pattern at each fertilization level (Table 17). WFNC digestibility values were significantly higher than those of the NFWC pattern at fertilization levels above 15 kg/ha (Table 18). A significantly lower IVDMD value only at the 75 kg/ha level was observed when NFNC (Table 19) was compared to DFNC. When NFNC was tested against NFDC, the NFNC pattern had significantly greater values at every level of fertilization with the exception of 75 kg/ha. Analysis of NFNC vs. WFNC showed the pattern receiving more moisture in the fallow period to have significantly lower IVDMD values at the four lowest levels of fertilization. NFNC vs. NFWC showed significantly lower digestibility for the NFWC regime at 0, 45, 60, and 105 kg/ha fertilization levels.

Table 16. Percent *in vitro* dry matter digestibility of wheat chaff under a normal fallow-normal crop precipitation pattern for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
NFNC	371	180	47.54	45.28	49.08	44.80	48.86	49.57

Table 17. Percent in vitro dry matter digestibility of wheat straw under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
DFNC	306	180	40.88[a]	41.27[a]	44.19[a]	43.92[a]	46.97[a]	44.22[a]
NFDC	371	133	39.01[b]	38.97[b]	39.87[b]	40.45[b]	43.22[b]	42.59[b]

[a,b]Means in the same colums with different superscripts differ (P < .05).

Table 18. Percent in vitro dry matter digestibility of wheat straw under two precipitation patterns for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
WFNC	488	201	38.80[a]	39.69[a]	42.77[a]	41.86[a]	44.37[a]	45.26[a]
NFWC	371	290	38.71[a]	40.86[a]	39.12[b]	39.48[b]	40.13[b]	39.00[b]

[a,b]Means in the same colums with different superxcripts differ (P < .05).

Table 19. Percent in vitro dry matter digestibility of wheat straw under a normal fallow-normal crop recipitation pattern for the crop year 1978-1979, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
NFNC	371	180	40.93	41.32	44.97	43.98	41.10	45.42

Percents of acid detergent fiber, lignin and cellulose were not significantly affected by precipitation variation or level of fertilization for either chaff or straw. Data are listed in Appendix tables 2, 3, 4, and 5.

1979-1980 Crop Year

Chaff yield was significantly affected by both precipitation ($P < .01$) and level of fertilization ($P < .05$). For a given level of total precipitation, analysis of DFNC vs. NFDC indicated that the pattern receiving less moisture in the fallow period had significantly lower yields at the four lowest fertilization levels, but significantly higher yields at the 75 and 105 kg/ha levels (Table 20). When testing the higher moisture regimes (Table 21), NFWC-1 had significantly higher yields at all fertilization levels except 15 and 75 kg/ha when compared to WFNC. NFWC-2 had higher yields than the WFNC pattern at the 45, 60, and 105 kg/ha levels. NFWC-1 had a significantly higher value than NFWC-2 at 0 kg/ha but a significantly lower value at 45 kg/ha. NFNC chaff yields (Table 22) were significantly lower than the DFNC pattern at the three highest fertilization levels and significantly lower at the 0, 45, and 60 kg/ha levels when tested against NFDC. NFNC vs. WFNC revealed significantly lower values for the WFNC pattern at all levels except 60 and 75 kg/ha. NFWC-1 yields were significantly higher than NFNC yields at only the 0 kg/ha level, but significantly lower at the 15 kg/ha level. The NFWC-2 pattern also had significantly lower yields than the NFNC pattern at the 15 kg/ha level, but was significantly higher at the 45 kg/ha level.

Table 20. Yield of wheat chaff under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
DFNC	237	389	224.75[a]	207.00[a]	272.75[a]	295.25[a]	367.75[a]	557.75[a]
NFDC	301	351	300.25[b]	411.00[b]	501.00[b]	465.75[b]	272.00[b]	299.25[b]

[a,b]Means in the same column with different superscripts differ ($P < .05$).

Table 21. Yield of wheat chaff under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
WFNC	418	389	186.50[c]	266.50[c]	220.00[c]	224.50[c]	300.25[c]	218.00[c]
NFWC-1[a]	301	426	310.50[d]	256.00[c]	277.00[d]	274.00[d]	312.25[c]	299.00[d]
NFWC-2[b]	301	426	223.75[c]	259.50[c]	338.25[e]	278.75[d]	293.00[c]	277.00[d]

[a]Precipitation treatment NFWC-1 received its allotment of fertilizer in one application.

[b]Precipitation treatment NFWC-2 received its allotment of fertilizer in two applications.

[c,d,e]Means in the same column followed by different superscripts differ ($P < .05$).

Wheat straw yield was significantly affected only by precipitation ($P < .01$). Contrasting DFNC and NFDC precipitation patterns indicated that the pattern receiving more moisture in the fallow period had significantly higher yields at every level of fertilization except 45 kg/ha (Table 23). Review of the WFNC, NFWC-1, and NFWC-2 patterns showed NFWC-1 to have significantly lower yields than WFNC (Table 24). NFWC-2 had significantly lower yields than WFNC at all levels except 60 and 105 kg/ha. NFWC-1 had significantly lower values than NFWC-2 at fertilization levels over 15 kg/ha. When testing the NFNC precipitation pattern (Table 25) with other patterns, DFNC had significantly lower yields at the 15, 45, and 105 kg/ha levels but significantly higher yields at the 60 kg/ha level. NFNC vs. NFDC revealed significantly higher yields for NFDC at every fertilization level except 45 kg/ha. Significantly higher yields were seen for the WFNC pattern when tested against NFNC at all but the highest level of fertilization. NFWC-1 straw yields were significantly higher at 0 kg/ha than the NFNC pattern and significantly lower at the 45 and 105 kg/ha levels. NFWC-2 yields were significantly lower than NFNC at the 15 kg/ha level but significantly higher at 60 and 75 kg/ha.

Percent crude protein of wheat chaff was significantly affected by both precipitation ($P < .01$) and fertilization level ($P < .01$). Testing DFNC vs. NFDC indicated that the pattern receiving more moisture in the fallow period had significantly higher values at the 0, 60, and 105 kg/ha levels and a significantly lower value at 75 kg/ha (Table 26). WFNC vs. NFWC (Table 27) revealed higher values for the NFWC-1 pattern at every fertilization level with the exception of 0 kg/ha. NFWC-2 had

Table 22. Yield of wheat chaff under a normal fallow-normal crop precipitation pattern for the crop year 1979-1980, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
NFNC	301	389	238.00	390.75	274.00	239.25	300.50	289.00

Table 23. Yield of wheat straw under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
DFNC	237	389	367.00[a]	369.75[a]	463.25[a]	461.75[a]	416.00[a]	394.25[a]
NFDC	301	351	512.25[b]	559.50[b]	491.00[a]	541.75[b]	574.75[b]	543.25[b]

[a,b]Means in the same column followed by different superscripts differ ($P < .05$).

Table 24. Yield of wheat straw under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
WFNC	418	389	557.00[c]	710.00[c]	573.25[c]	485.75[c]	699.75[c]	477.25[c]
NFWC-1[a]	301	426	450.25[d]	461.75[d]	421.25[d]	387.75[d]	414.50[d]	398.50[d]
NFWC-2[b]	301	426	411.50[d]	398.75[e]	517.00[e]	472.25[c]	559.25[e]	473.75[c]

[a]Precipitation treatment NFWC-1 received its allotment of fertilizer in one application.

[b]Precipitation treatment NFWC-2 received its allotment of fertilizer in two applications.

[c,d,e]Means in the same column followed by different superscripts differ ($P < .05$).

Table 25. Yield of wheat straw under a normal fallow-normal crop precipitation pattern for the crop year 1979-1980, Sherman County, Oregon (g./4.8 m. subplot).

Treat-ment	Precipitation received (mm) fallow	Precipitation received (mm) crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
NFNC	301	389	385.75	488.25	516.50	406.25	454.75	452.50

Table 26. Percent crude protein of wheat chaff under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
DFNC	237	389	3.02[a]	2.75[a]	2.73[a]	2.66[a]	3.39[a]	2.73[a]
NFDC	301	351	3.28[b]	2.82[a]	2.78[a]	3.06[b]	2.60[b]	3.07[b]

[a,b]Means in the same column followed by different superscripts differ (P < .05).

Table 27. Percent crude protein of wheat chaff under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
WFNC	418	389	2.33[c]	2.20[c]	2.26[c]	2.44[c]	2.60[c]	2.41[c]
NFWC-1[a]	301	426	2.44[c]	2.64[d]	2.51[d]	2.70[d]	3.61[d]	3.72[d]
NFWC-2[b]	301	426	2.27[c]	2.82[d]	2.69[d]	2.49[c]	2.49[c]	2.95[e]

[a]Precipitation treatment NFWC-1 received its allotment of fertilizer in one application

[b]Precipitation treatment NFWC-2 received its allotment of fertilizer in two applications.

[c,d,e]Means in the same column followed by different superscripts differ (P < .05).

significantly higher protein values than WFNC at the 15, 45, and 105 kg/ha levels. Analysis of NFNC (Table 28) and DFNC indicated significantly higher values for DFNC at the 45, 60, and 75 kg/ha levels. NFDC, when compared to NFNC, had significantly lower values at 0 and 75 kg/ha, but higher values at 45 and 60 kg/ha. With the exception of 45 and 60 kg/ha, the WFNC pattern had significantly lower values than the NFNC pattern at every fertilization level. NFNC vs. NFWC-1 revealed significantly lower values at the two lowest levels of fertilization, but significantly higher protein values at levels above 45 kg/ha. However, NFWC-2 vs. NFNC showed significantly lower values for the NFWC-2 pattern at the 0 and 75 kg/ha level.

Unlike wheat chaff, percent crude protein for wheat straw was significantly affected only by precipitation ($P < .01$). Comparison of DFNC and NFDC patterns demonstrated significantly higher values at the 15, 45, 75, and 105 kg/ha levels and significantly lower values only at the 0 kg/ha level for the DFNC pattern (Table 29). WFNC vs. NFWC patterns revealed significantly higher values for the pattern receiving less moisture in the fallow period at all fertilization levels except 45 kg/ha (Table 30). In the analysis of NFNC (Table 31) vs. DFNC, higher protein values were seen for the DFNC pattern at the 45, 75, and 105 kg/ha levels, but lower values at the 0 and 60 kg/ha levels. NFNC vs. NFDC showed NFDC to have a significantly higher protein value only at 45 kg/ha and a significantly lower value only at the 60 kg/ha level. When evaluating NFNC vs. WFNC, the pattern receiving more moisture in the fallow period had significantly lower values at every level of fertilization except 45 kg/ha. In testing NFNC vs. NFWC-1, the pattern

Table 28. Percent crude protein of wheat chaff under a normal fallow-normal crop precipitation pattern in the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
NFNC	301	389	2.90	2.94	2.42	2.36	3.12	2.93

Table 29. Percent crude protein of wheat straw under two precipitation patterns in the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm) fallow	crop	Fertilization Level (kg. N/ha.) 0	15	45	60	75	105
DFNC	237	389	1.55[a]	1.93[a]	2.04[a]	1.83[a]	2.02[a]	2.22[a]
NFDC	301	351	2.12[b]	1.62[b]	1.87[b]	1.73[a]	1.61[b]	1.93[b]

[a,b]Means in the same column followed by different superscripts differ ($P < .05$).

Table 30. Percent crude protein of wheat straw under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
WFNC	418	389	1.47[c]	1.48[c]	1.55[c]	1.36[c]	1.50[c]	1.42[c]
NFWC-1[a]	301	426	1.97[d]	1.68[d]	1.71[c]	1.91[d]	2.00[d]	2.27[d]
NFWC-2[b]	301	426	1.71[e]	1.83[d]	1.81[c]	1.96[d]	1.70[e]	1.83[e]

[a]Precipitation treatment NFWC-1 received its allotment of fertilizer in one application.

[b]Precipitation treatment NFWC-2 received its allotment of fertilizer in two applications.

[c,d,e]Means in the same column with different superscripts differ ($P < .05$).

Table 31. Percent crude protein of wheat straw under a normal fallow-normal crop preciptiation pattern for the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)							
	fallow	crop	0	15	45	60	75	105
NFNC	301	389	2.04	1.77	1.64	2.18	1.79	1.81

receiving more moisture overall had significantly lower crude protein values at 60 kg/ha, but significantly higher values at fertilization levels over that amount. NFWC-2 had significantly lower values than did NFNC at the 0 and 60 kg/ha fertilization levels.

The percent in vitro dry matter digestibility (IVDMD) of wheat straw was significantly affected by precipitation ($P < .05$). Examination of DFNC vs. NFDC indicated significantly higher values for the NFDC pattern at only the two lowest fertilization levels (Table 32). NFWC-1 had significantly lower values at every level of fertilization with the exception of 0 kg/ha, when compared to WFNC (Table 33). When testing WFNC with NFWC-2, the pattern receiving less moisture in the fallow period had significantly lower digestibility values at fertilization levels above 15 kg/ha. NFWC-1 had significantly lower values only at the 15 and 60 kg/ha levels when compared to NFWC-2, but significantly higher values at 0 and 75 kg/ha levels of fertilization (Table 33). Analysis of NFNC (Table 34) vs. the low moisture regimes indicated significantly lower values at 0 and 15 kg/ha for the DFNC pattern, but significantly higher values at 75 and 105 kg/ha. NFNC vs. NFDC showed significantly higher values at the 0, 15, 75, and 105 kg/ha fertilization levels for the NFDC precipitation pattern. The WFNC pattern had significantly lower values at 0 kg/ha than did the NFNC pattern, but significantly higher values at fertilization levels above 15 kg/ha. NFNC vs. NFWC-1 revealed a significantly lower value for NFWC-1 at 15 kg/ha but significantly higher values at 75 and 105 kg/ha. NFWC-2 had significantly lower IVDMD values than did NFNC at 0 kg/ha but was significantly higher at 60 kg/ha.

As was seen in the previous crop year, percentages of acid detergent fiber, lignin and cellulose in the crop year 1979-1980 were not significantly affected by precipitation variation or level of fertilization for either chaff or straw (Appendix tables 7, 8, 9, and 10).

Table 32. Percent *in vitro* dry matter digestibility of wheat straw under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop	0	15	45	60	75	105
DFNC	237	389	37.53[a]	39.58[a]	42.63[a]	39.90[a]	42.96[a]	45.49[a]
NFDC	301	351	48.17[b]	48.15[b]	42.72[a]	41.28[a]	44.15[a]	43.36[a]

[a,b]Means in the same column followed by different superscripts differ (P < .05).

Table 33. Percent *in vitro* dry matter digestibility of wheat straw under two precipitation patterns for the crop year 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)							
	fallow	crop	0	15	45	60	75	105
WFNC	418	389	42.23[c]	44.62[c]	44.70[c]	46.92[c]	45.29[c]	49.52[c]
NFWC-1[a]	301	426	46.48[d]	40.42[d]	41.59[d]	41.09[d]	43.80[d]	39.72[d]
NFWC-2[b]	301	426	41.13[c]	43.67[c]	40.37[d]	43.59[e]	40.98[e]	38.04[d]

[a]Precipitation treatment NFWC-1 received its allotment of fertilizer in one application.

[b]Precipitation treatment NFWC-2 received its allotment of fertilizer in two applications.

[c,d,e]Means in the same column followed by different superscripts differ (P < .05).

Table 34. Percent *in vitro* dry matter digestibility of wheat straw under a normal fallow-normal crop precipitation pattern for the crop year, 1979-1980, Sherman County, Oregon.

Treat-ment	Precipitation received (mm)		Fertilization Level (kg. N/ha.)					
	fallow	crop						
NFNC	301	389	45.43	43.08	41.67	40.51	38.52	37.90

SUMMARY AND CONCLUSIONS

This study indicated that higher moisture regimes resulted in increased straw and chaff yields. Although not significant for every precipitation pattern, there was indication of a positive relationship between fertilization level and straw and chaff yields. Percentage crude protein of wheat straw and chaff was most affected by the high moisture patterns, although the improvement seen over that of the lower moisture regimes was not great. Percentage *in vitro* dry matter digestibility was also most increased under the high moisture precipitation patterns and there was a positive relationship between fertilization level and digestibility. Acid detergent fiber, lignin and cellulose levels were not affected by precipitation variation or level of fertilization. With the exception of percent crude protein of wheat straw in the first year, the fertilization level by precipitation variation interaction was not a significant source of variation.

Where cattle are raised as a supplementary enterprise to wheat, cereal crop residues are an important part of the feed source. Utilization of crop residues in beef cow forage systems can reduce beef production costs and the amount of land needed for alternative forage production. In cereal crop production systems, management decisions regarding nitrogen fertilization are made after estimating grain potential and predicting future levels of precipitation based on both current conditions and the analysis of long term precipitation summaries.

Specific growing conditions each year are an important consideration in determining residue quality. Many factors combine to create any specific condition. Two of the most important are: 1) moisture availability and timing of stress; 2) fertilization practices. These factors affect nutrient uptake and translocation processes, which in turn influence cereal residue quality. Once fertilization application levels have been determined, information from this study could be used by a farmer to predict the relative yield and nutrient content of the crop residue for future livestock use. These predictions would enable him to make more accurate decisions regarding potential carrying capacity and supplementation requirements, thus providing increased livestock production at minimum cost.

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APPENDICES

Appendix 1. Fallow-crop precipitation pattern treatments[a]

Pattern	Projected levels of precipitation (mm)			Realized levels of precipitation (mm)					
				1977-1979			1978-1980		
	14 mo. Fallow	May-Sept.	10 mo. crop	Fallow	May-Sept.	Crop	Fallow	May-Sept.	Crop
DFNC	230	47	270	306	64	180	237	52	389
NFDC	310	67	200	371	79	133	301	52	351
NFNC	310	67	270	371	79	180	301	52	389
NFWC	310	67	390	371	79	290	301	52	426
WFNC	415	78	270	488	130	201	418	85	389
control				422	79	180	263	39	389

[a]Glenn (1981)

Appendix 2. Percentage of acid detergent fiber, lignin and cellulose of wheat chaff under three precipitation patterns for the crop year 1978-1979, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
DFNC	0	44.49	5.22	33.68
	15	42.28	4.87	32.88
	45	40.71	4.66	32.74
	60	42.22	4.66	32.85
	75	42.62	5.08	32.75
	105	40.71	4.94	32.20
NFDC	0	44.43	5.77	33.03
	15	42.97	5.39	33.31
	45	42.89	5.27	33.36
	60	42.07	5.25	32.87
	75	41.52	5.23	32.95
	105	41.85	5.20	32.62
NFNC	0	42.57	5.17	32.31
	15	42.95	5.04	33.80
	45	43.00	5.57	33.63
	60	43.96	5.29	33.32
	75	41.35	4.80	32.72
	105	42.00	4.82	32.44

[a]Each value represents the mean for four samples.

Appendix 3. Percentages of acid detergent fiber, lignin and cellulose of wheat chaff under three precipitation patterns for the crop year 1978-1979, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
NFWC	0	46.29	4.86	33.60
	15	42.92	5.61	33.44
	45	42.85	5.38	32.50
	60	40.86	4.86	32.07
	75	44.04	6.45	33.80
	105	38.72	4.49	32.08
WFNC	0	40.70	4.94	32.11
	15	42.06	4.58	32.28
	45	40.58	4.69	32.10
	60	42.46	5.10	33.20
	75	41.47	5.18	33.02
	105	40.03	4.33	33.07
control	0	45.99	5.60	32.44
	15	45.06	5.31	33.62
	45	41.51	5.14	32.45
	60	42.09	4.76	32.38
	75	42.45	4.62	32.36
	105	41.75	5.51	32.84

[a]Each value represents the mean for four samples.

Appendix 4. Percentages of acid detergent fiber, lignin, and cellulose of wheat straw under three precipitation patterns for the crop year 1978-1979, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
DFNC	0	45.69	6.62	34.99
	15	46.18	6.68	37.31
	45	43.51	6.70	35.54
	60	44.74	6.18	35.67
	75	44.12	6.58	34.69
	105	44.80	6.62	35.35
NFDC	0	46.99	5.81	35.97
	15	45.67	7.25	36.66
	45	45.30	6.68	35.65
	60	46.35	5.93	36.38
	75	45.91	5.65	36.13
	105	44.78	7.11	35.46
NFNC	0	45.08	5.85	34.89
	15	46.09	6.28	36.07
	45	45.28	6.91	34.74
	60	45.52	5.07	37.34
	75	46.34	6.14	35.89
	105	45.56	6.46	36.02

[a]Each value represents the mean for four samples.

Appendix 5. Percentages of acid detergent fiber, lignin, and cellulose of wheat straw under three precipitation patterns for the crop year 1978-1979, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
NFWC	0	47.90	7.62	37.90
	15	47.68	5.64	37.63
	45	47.07	5.68	37.57
	60	46.28	6.13	37.96
	75	46.45	6.22	39.85
	105	47.02	5.38	35.93
WFNC	0	47.32	6.74	37.04
	15	46.44	6.33	37.88
	45	45.42	7.43	35.51
	60	45.43	6.00	35.67
	75	43.93	6.05	35.34
	105	44.92	6.85	35.02
control	0	47.90	6.93	36.91
	15	46.28	7.03	35.86
	45	46.82	6.12	36.44
	60	45.81	5.55	35.98
	75	45.46	6.77	36.49
	105	44.21	6.79	35.43

[a]Each value represents the mean for four samples.

Appendix 6. Yield, percent crude protein, and percent *in vitro* dry matter digestibility (IVDMD) of wheat chaff and straw under the control treatment in the crop year 1978-1979, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Yield (g/4.8 m. subplot)[a]	Crude protein %[a]	IVDMD %[a]
control-chaff	0	158.00	2.82	42.27
	15	127.25	3.01	40.83
	45	176.00	3.33	45.62
	60	170.00	3.28	48.56
	75	179.00	3.61	50.06
	105	163.00	3.78	50.75
control-straw	0	253.25	1.81	36.55
	15	243.50	2.15	41.24
	45	270.00	2.14	39.48
	60	285.25	2.43	39.95
	75	292.00	2.44	40.55
	105	288.50	2.77	41.18

[a]Each value represents the mean for four samples.

Appendix 7. Percentages of acid detergent fiber, lignin, and cellulose of wheat chaff under three precipitation patterns for the crop year 1979-1980, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
DFNC	0	38.58	4.29	30.38
	15	44.02	4.50	33.94
	45	43.95	5.92	33.65
	60	42.46	4.34	33.52
	75	41.62	4.42	33.95
	105	47.65	5.57	33.78
NFDC	0	46.04	4.82	38.19
	15	46.60	4.92	35.48
	45	45.75	4.65	37.41
	60	39.75	4.92	28.98
	75	45.49	4.58	31.41
	105	42.68	5.22	33.11
NFNC	0	43.07	4.81	35.64
	15	42.01	4.20	32.60
	45	44.32	4.72	33.17
	60	43.79	4.72	33.19
	75	43.49	5.00	31.90
	105	43.85	5.98	31.24

[a]Each value represents the mean for four samples.

Appendix 8. Percentages of acid detergent fiber, lignin and cellulose of wheat chaff under three precipitation patterns for the crop year 1979-1980, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
NFWC-1	0	48.95	5.06	32.91
	15	44.64	6.60	32.01
	45	48.38	5.47	33.48
	60	45.49	5.52	35.13
	75	43.01	4.90	30.91
	105	41.56	5.58	32.29
NFWC-2	0	43.88	5.18	31.38
	15	43.27	5.12	33.24
	45	44.03	5.32	33.77
	60	44.59	4.18	35.36
	75	45.85	4.90	34.41
	105	44.88	5.32	34.96
WFNC	0	44.91	5.11	32.17
	15	44.08	5.72	31.56
	45	43.75	5.67	30.79
	60	43.91	4.93	28.35
	75	41.42	4.59	30.57
	105	40.64	3.57	29.39
control	0	43.98	5.09	33.07
	15	41.36	4.25	30.17
	45	43.29	5.27	33.89
	60	44.01	4.60	35.79
	75	44.29	5.60	33.63
	105	47.39	5.87	33.88

[a]Each value represents the mean for four samples.

Appendix 9. Percentages of acid detergent fiber, lignin and cellulose of wheat straw under three precipitation patterns for the crop year 1979-1980, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
DFNC	0	45.17	6.46	34.54
	15	45.27	7.06	34.48
	45	45.95	7.38	35.01
	60	46.30	7.59	35.36
	75	46.18	5.32	36.68
	105	44.70	6.42	34.72
NFDC	0	45.31	6.67	34.79
	15	45.63	7.48	34.69
	45	48.22	6.47	37.36
	60	46.77	7.34	34.73
	75	47.48	7.11	35.31
	105	45.56	7.12	34.91
NFNC	0	45.64	6.57	36.14
	15	46.55	5.16	36.41
	45	44.90	5.53	34.64
	60	44.83	6.03	35.10
	75	47.33	6.55	37.41
	105	46.09	6.98	36.31

[a]Each value represents the mean for four samples.

Appendix 10. Percentages of acid detergent fiber, lignin and cellulose of wheat straw under three precipitation patterns for the crop year 1979-1980, Sherman County, Oregon

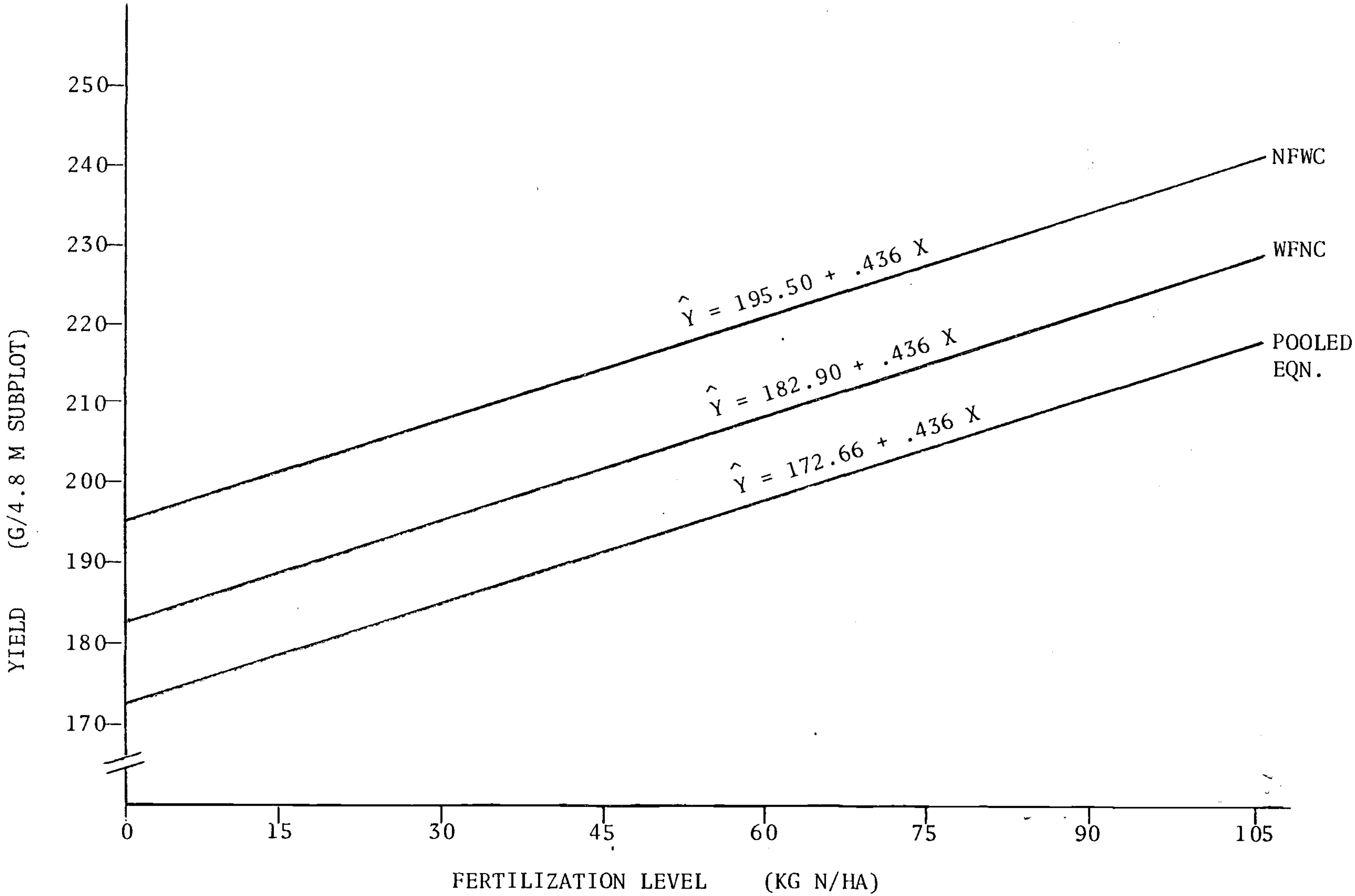
Treatment	Level of fertilization (kg. N/ha)	Acid detergent fiber, %[a]	Lignin, %[a]	Cellulose, %[a]
NFWC-1	0	44.91	5.96	34.00
	15	45.96	6.53	35.26
	45	46.98	5.98	35.62
	60	48.84	8.02	36.94
	75	46.38	7.91	36.07
	105	44.58	6.57	35.08
NFWC-2	0	44.07	6.07	34.35
	15	44.69	7.98	34.89
	45	46.50	7.38	35.62
	60	46.40	7.07	36.40
	75	45.75	4.76	35.29
	105	46.22	6.35	36.37
WFNC	0	43.87	6.54	31.88
	15	42.53	6.83	32.19
	45	43.98	6.41	32.20
	60	43.38	6.85	32.66
	75	43.63	7.11	32.61
	105	41.60	7.30	32.65
control	0	44.54	7.32	34.20
	15	45.54	5.54	33.93
	45	46.48	6.44	36.15
	60	46.67	8.46	36.11
	75	46.08	7.61	35.42
	105	45.57	7.16	34.56

[a]Each value represents the mean of four samples.

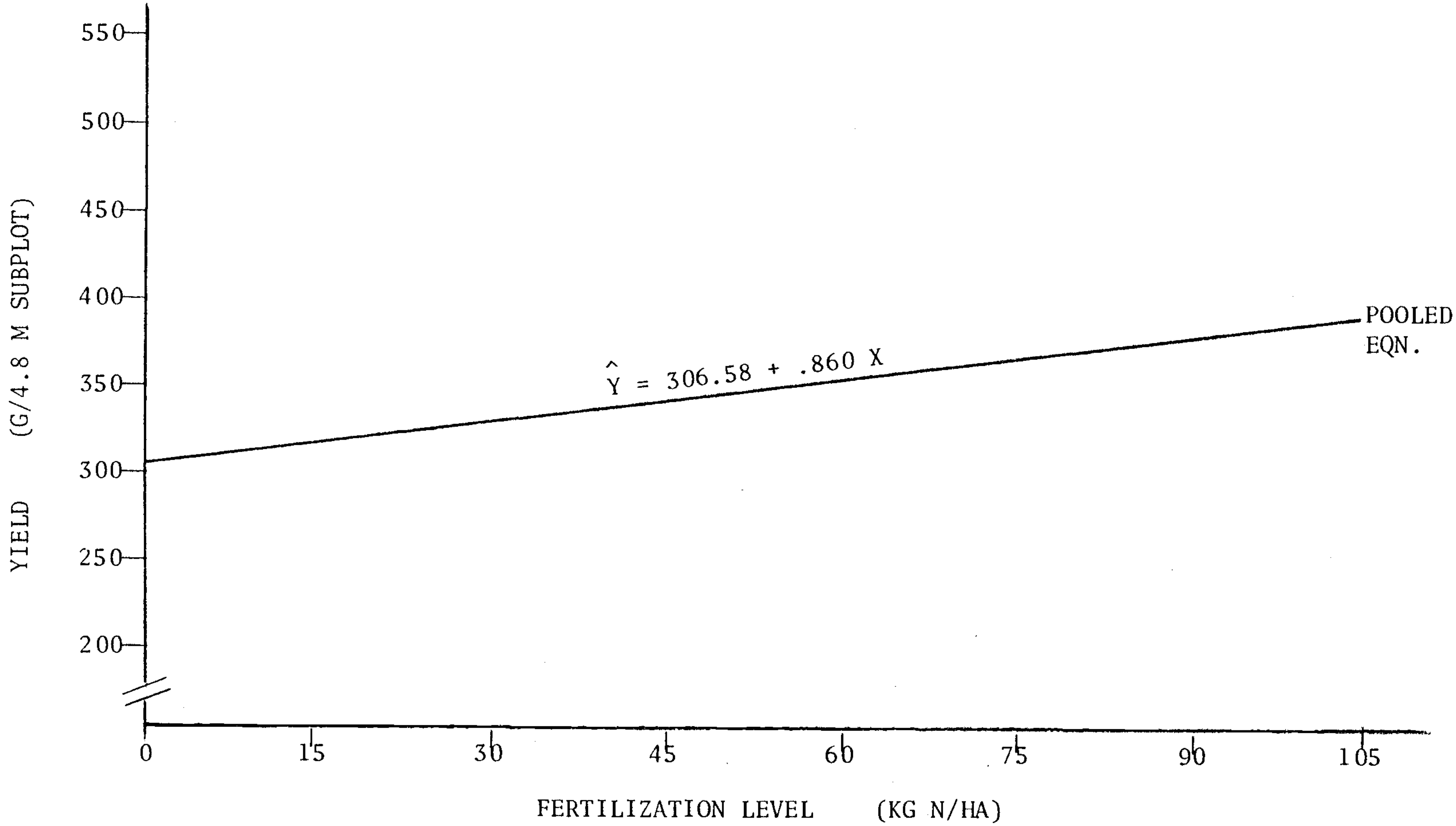
Appendix 11. Yield, percent crude protein, and percent in vitro dry matter digestibility (IVDMD) of wheat chaff and straw under the control treatment in the crop year 1979-1980, Sherman County, Oregon

Treatment	Level of fertilization (kg. N/ha)	Yield (g/4.8 m. subplot)[a]	Crude protein %[a]	IVDMD %[a]
control-chaff	0	223.50	2.48	43.56
	15	291.00	2.78	44.23
	45	282.00	2.88	45.21
	60	328.75	3.08	44.64
	75	303.75	2.44	45.91
	105	268.00	2.86	46.91
control-straw	0	623.00	1.78	41.00
	15	526.25	1.53	42.29
	45	439.00	1.60	37.64
	60	500.50	2.07	41.26
	75	618.00	1.80	37.31
	105	521.50	2.05	42.20

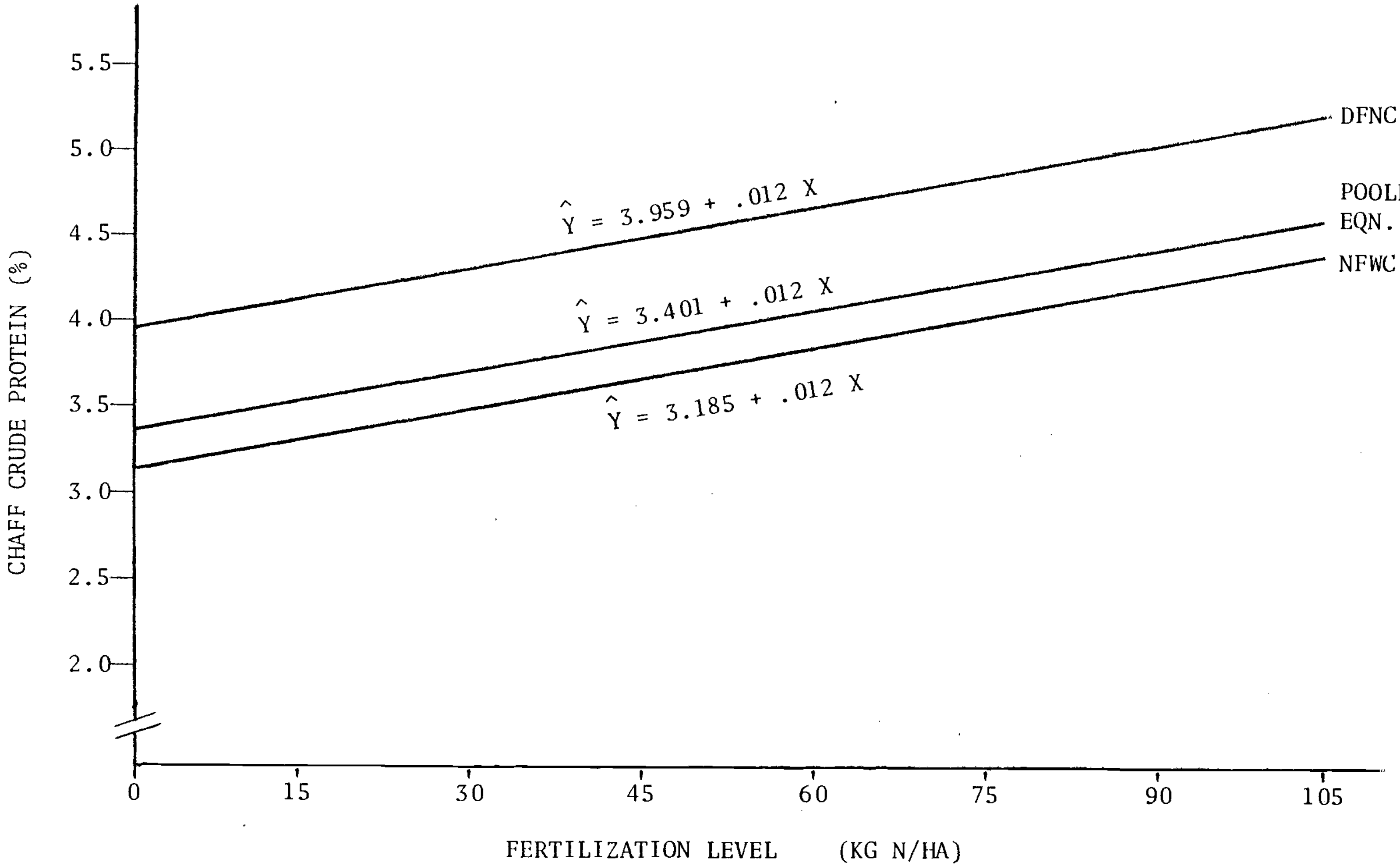
[a]Each value represents the mean for four samples.



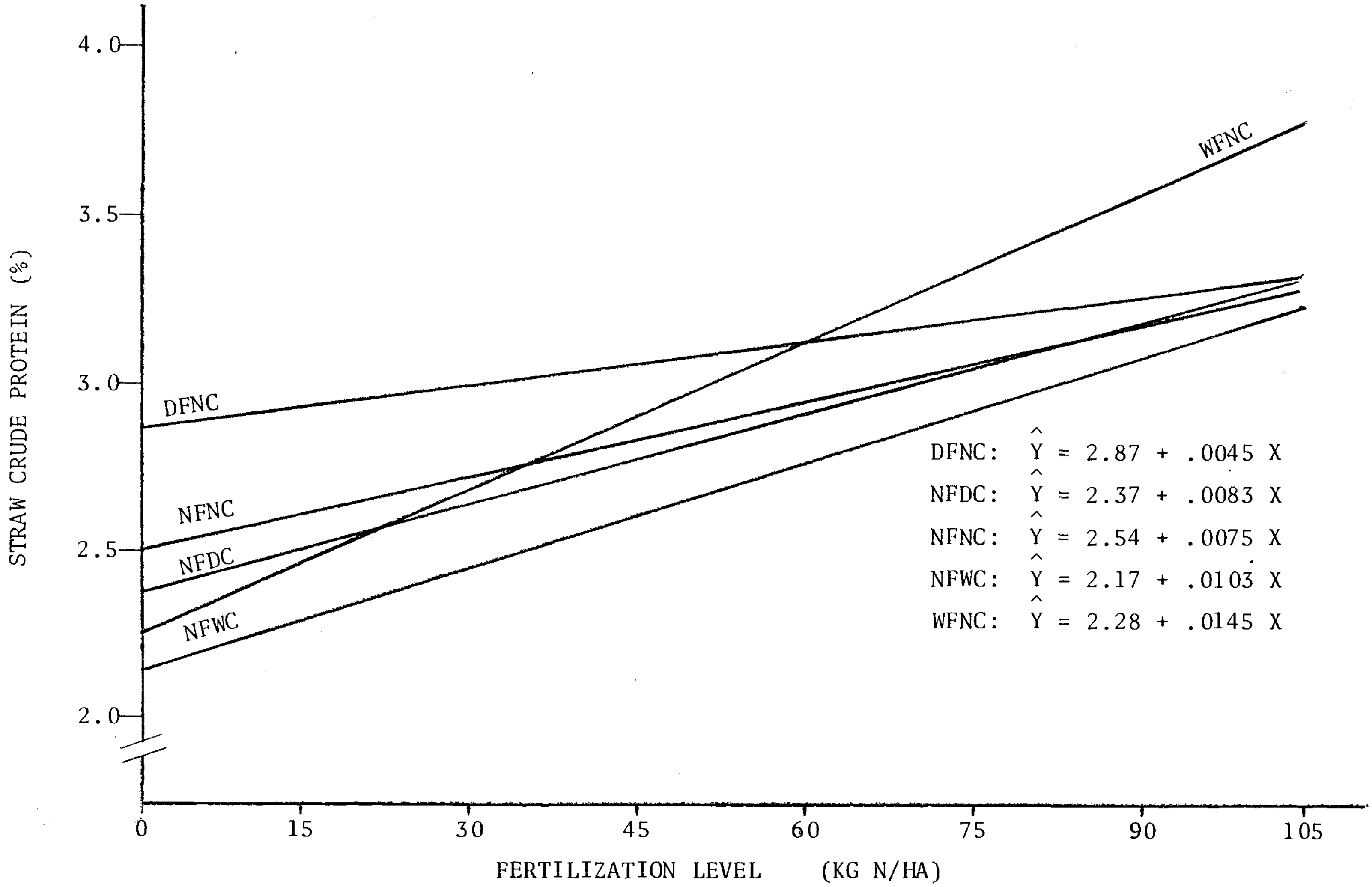
Appendix 12. Response of chaff yield to nitrogen fertilizer, 1978-1979 crop year.



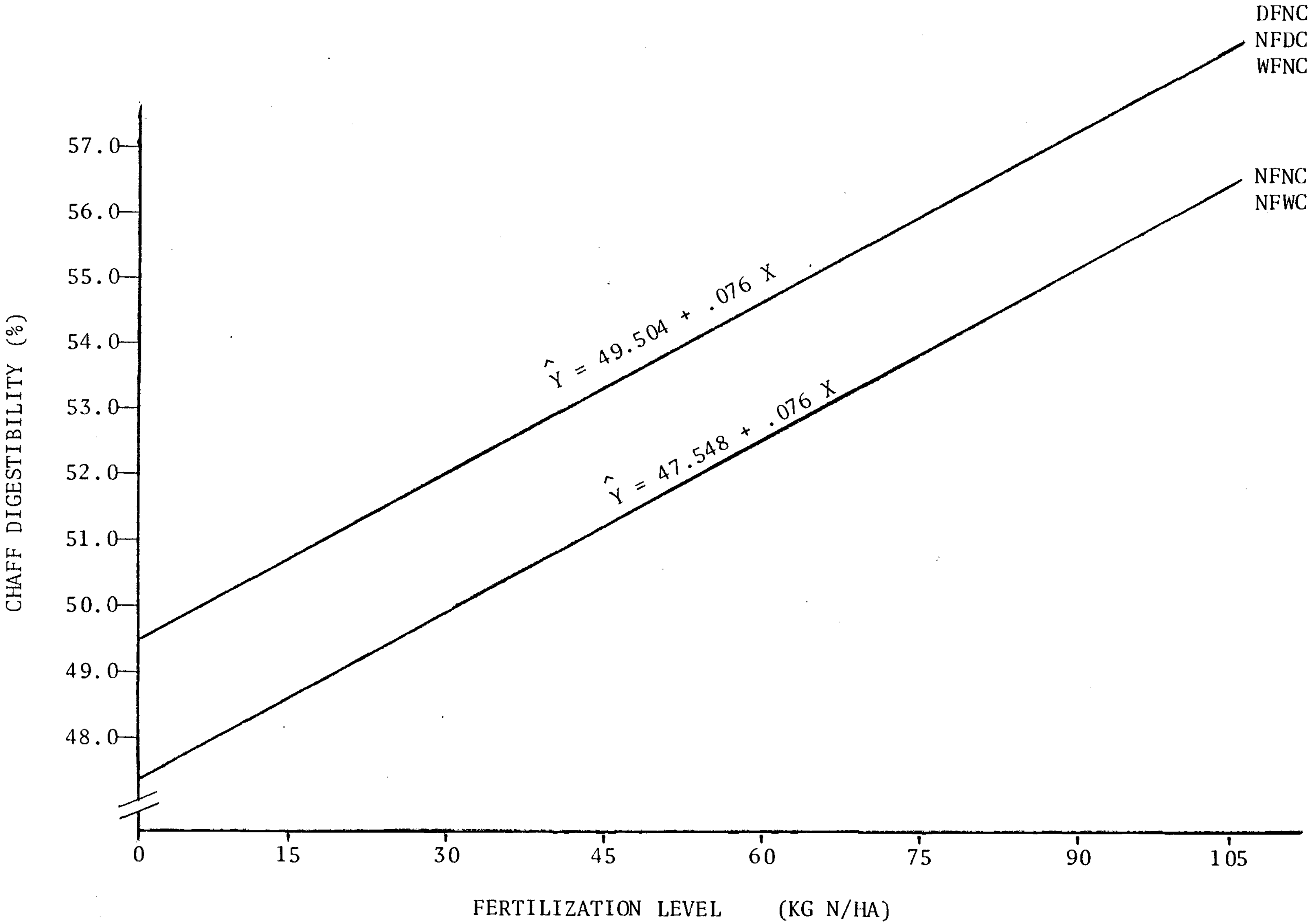
Appendix 13. Response of straw yield to nitrogen fertilizer, 1978-1979 crop year.



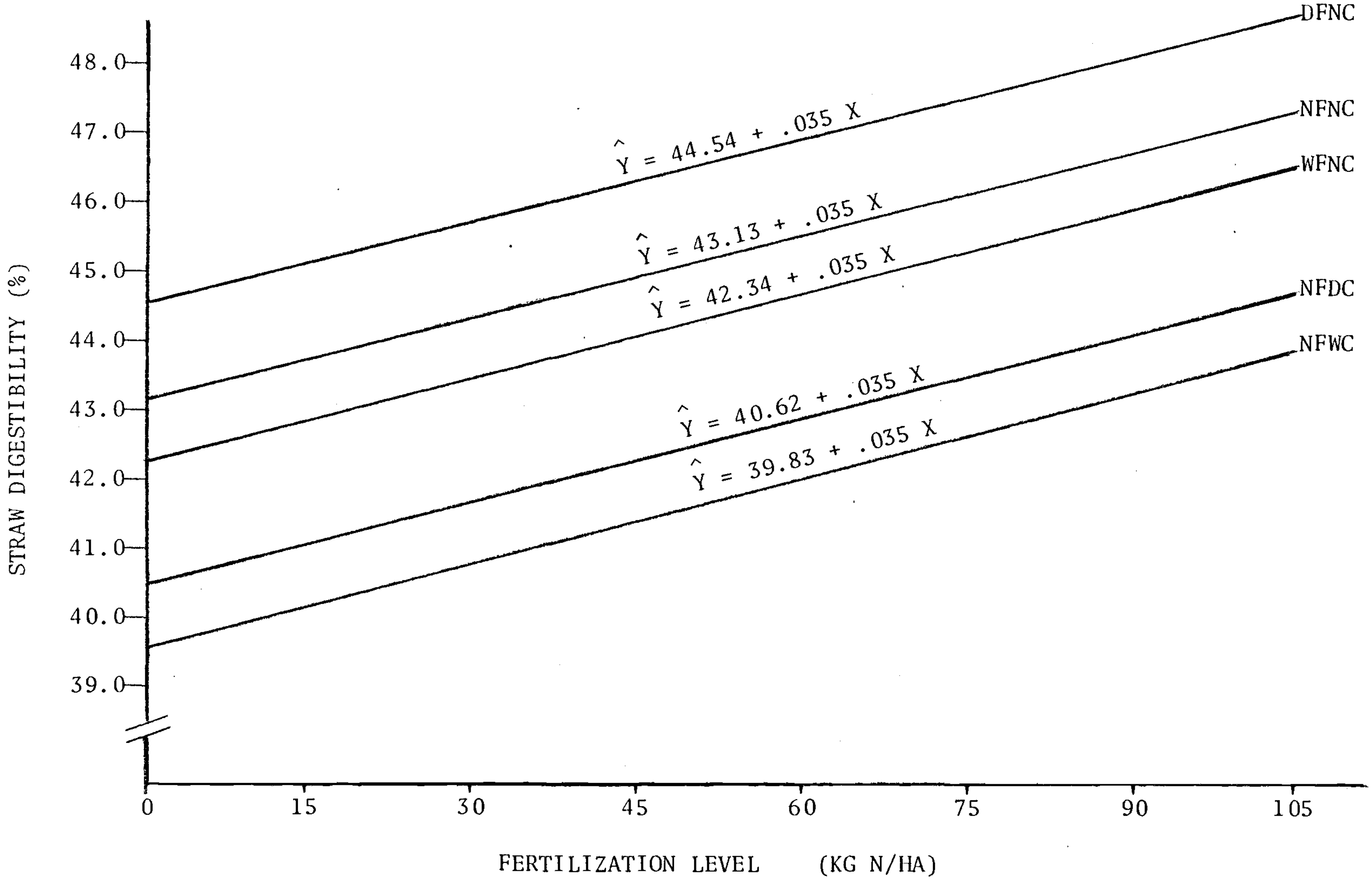
Appendix 14. Response of chaff crude protein to nitrogen fertilizer, 1978-1979 crop year.



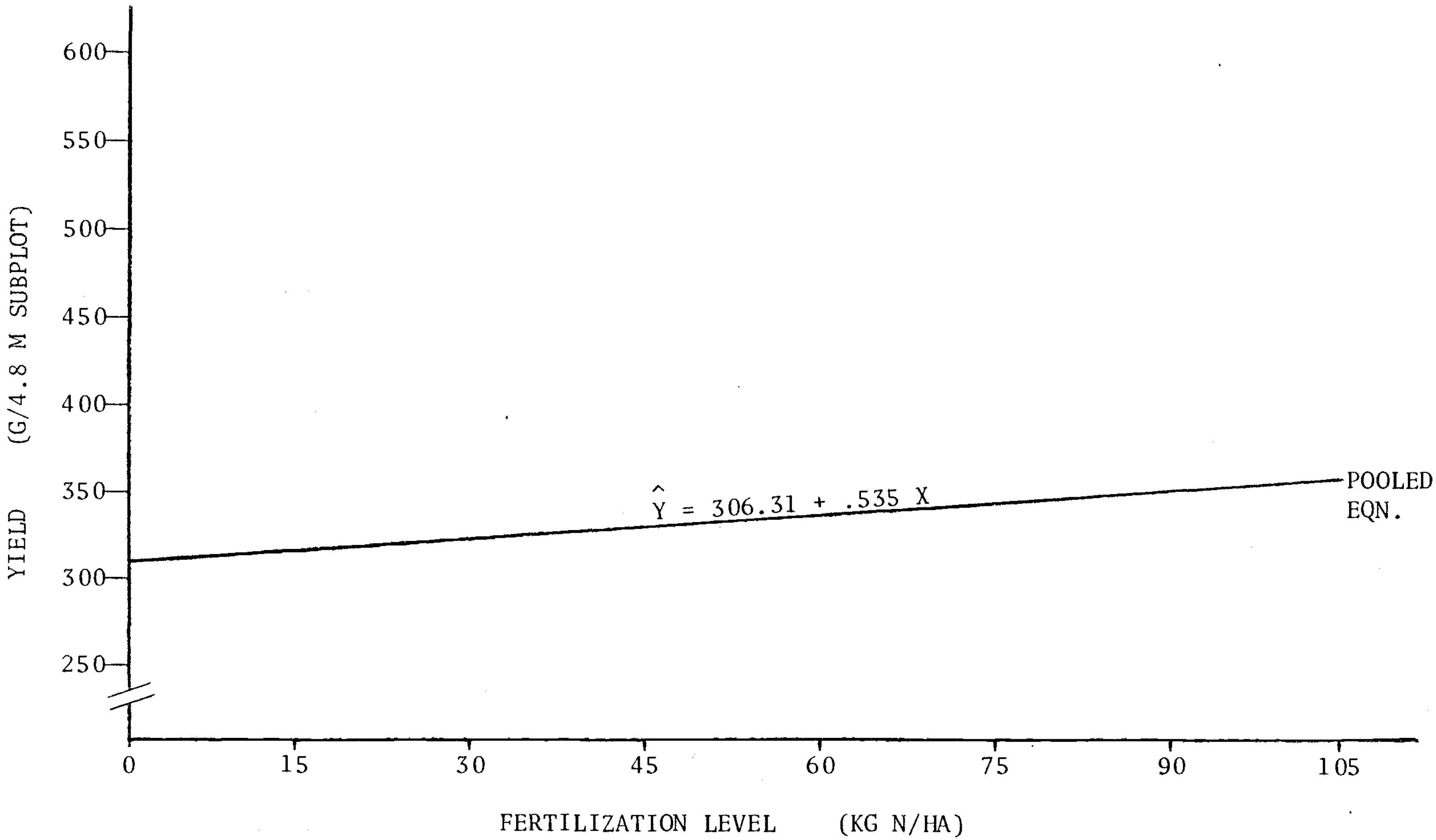
Appendix 15. Response of straw crude protein to nitrogen fertilizer, 1978-1979 crop year.



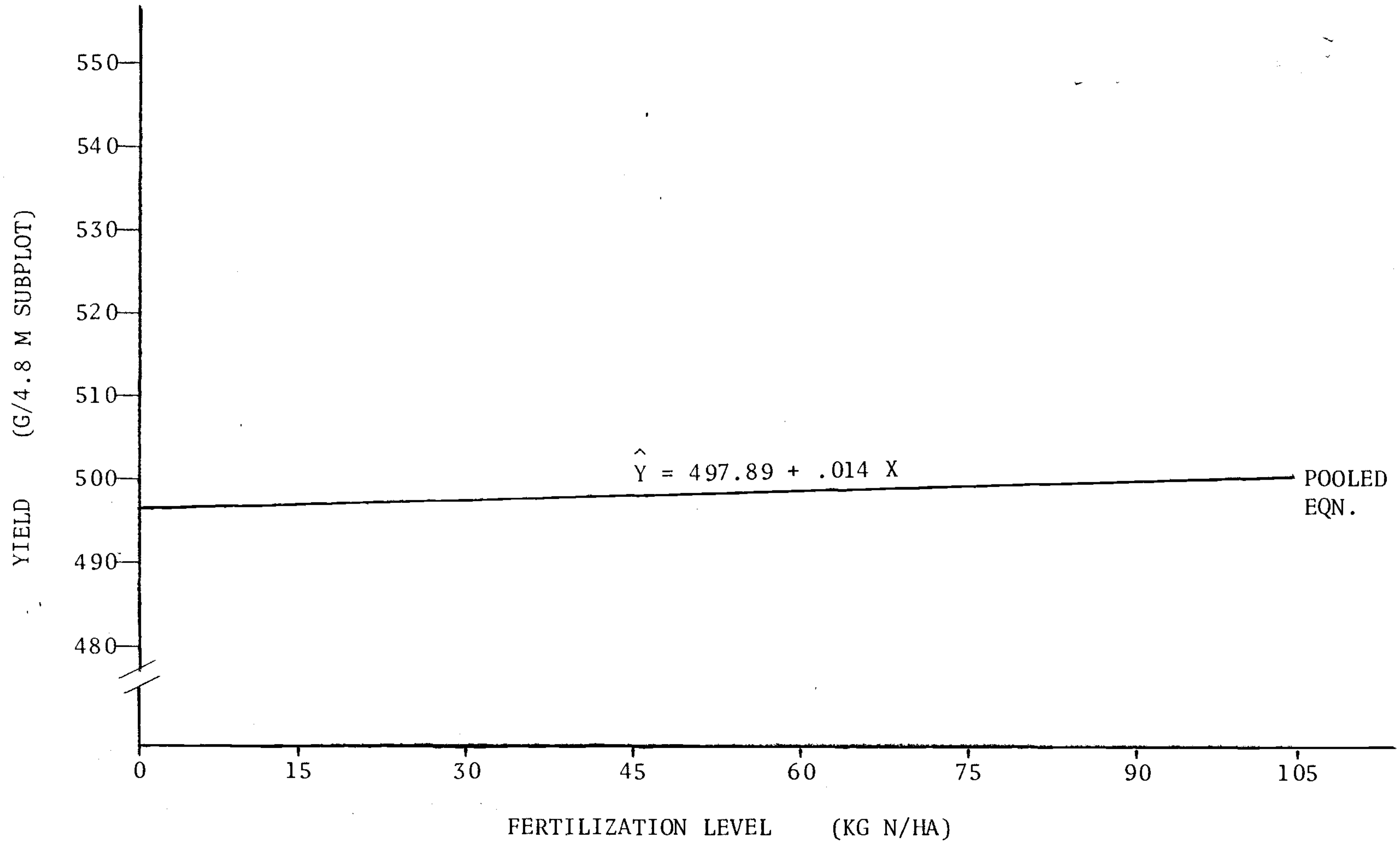
Appendix 16. Response of chaff *in vitro* dry matter digestibility to nitrogen fertilizer, 1978-1979 crop year.



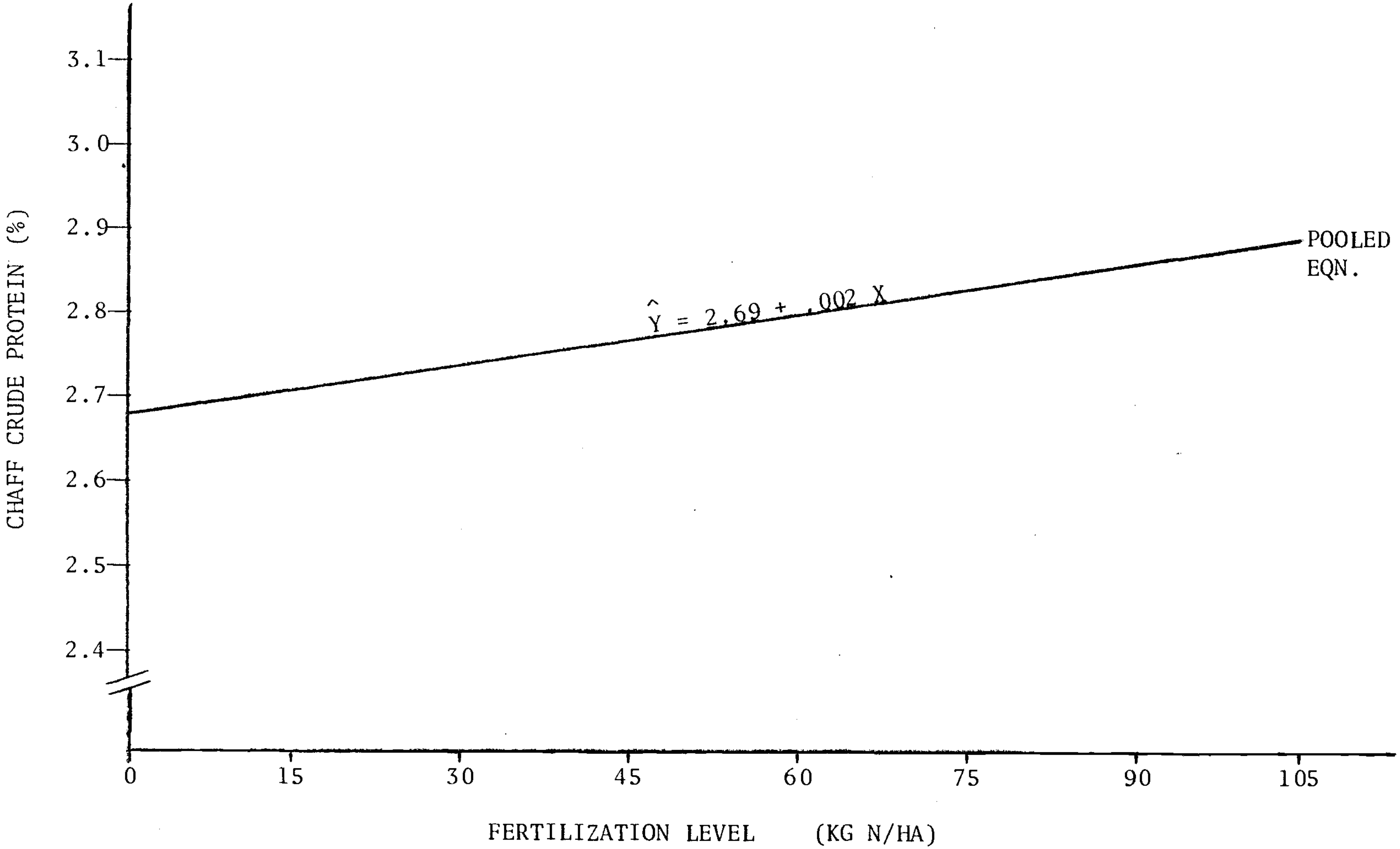
Appendix 17. Response of straw *in vitro* dry matter digestibility to nitrogen fertilizer, 1978-1979 crop year.



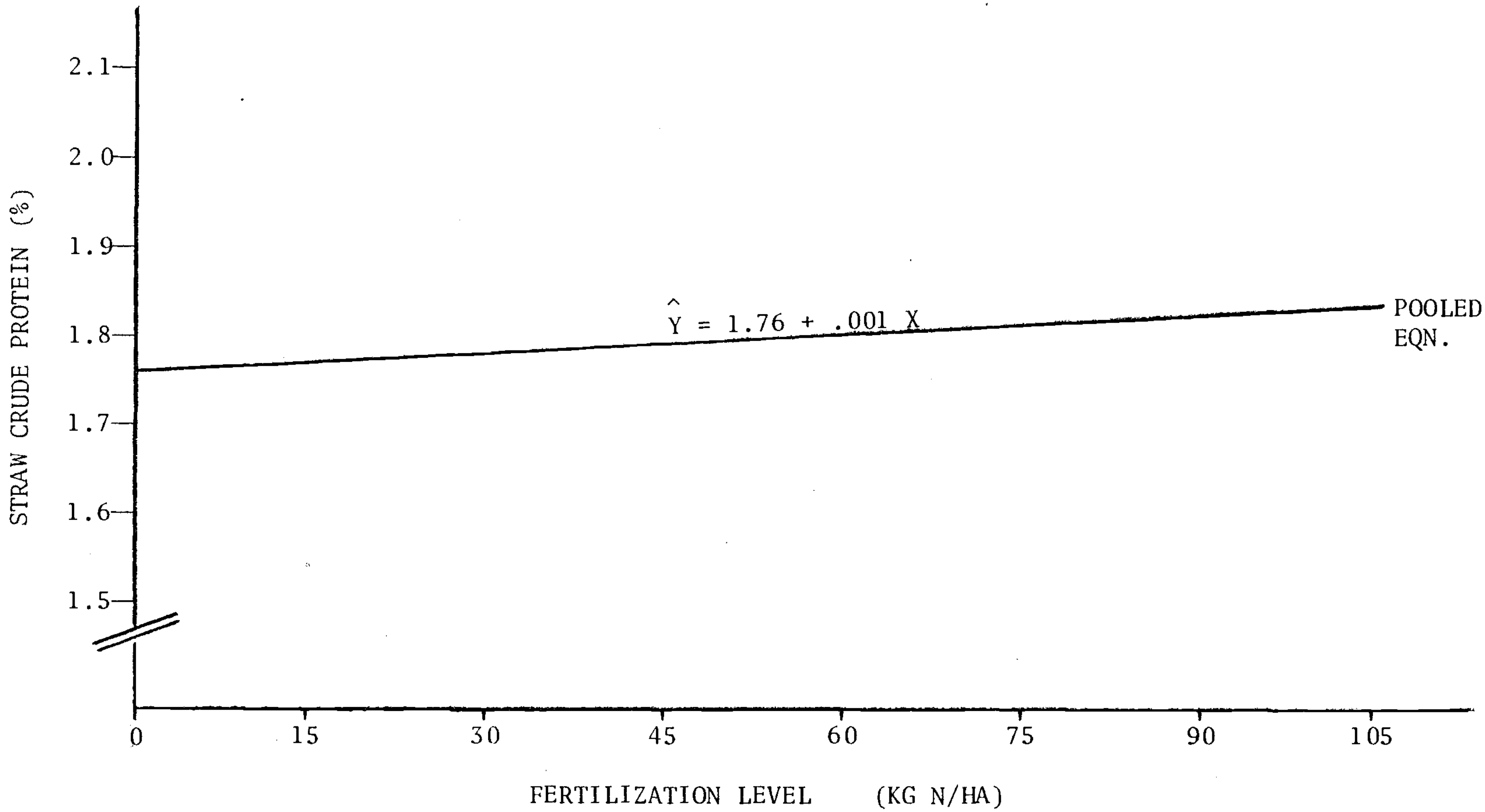
Appendix 18. Response of chaff yield to nitrogen fertilizer, 1979-1980 crop year.



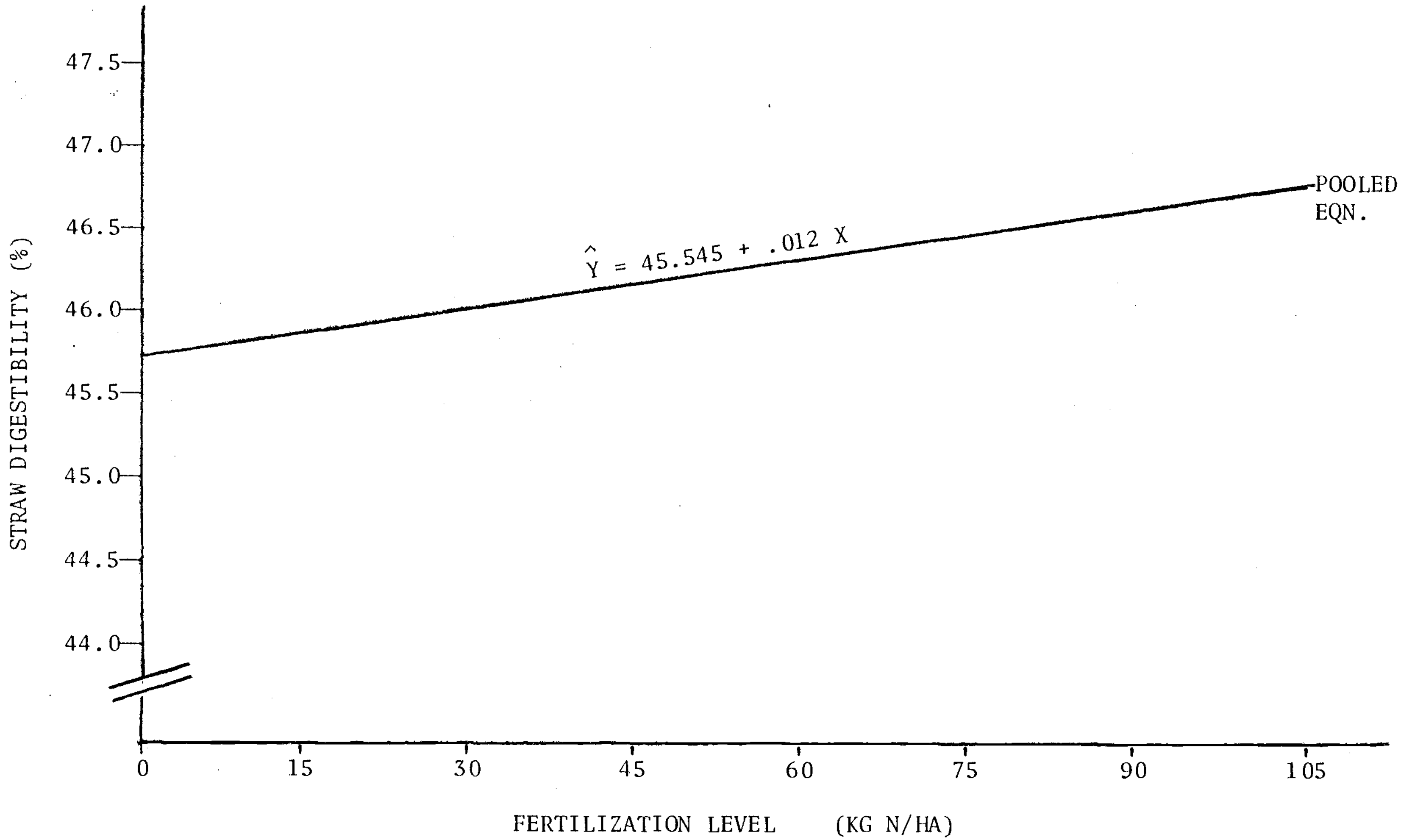
Appendix 19. Response of straw yield to nitrogen fertilizer, 1979-1980 crop year.



Appendix 20. Response of chaff crude protein to nitrogen fertilizer, 1979-1980 crop year.



Appendix 21. Response of straw crude protein to nitrogen fertilizer, 1979-1980 crop year.



Appendix 22. Response of straw in vitro dry matter digestibility to nitrogen fertilizer, 1979-1980 crop year.