SOME EFFECTS OF TREATED MUNICIPAL WASTEWATER
ON OATS (Avena sativa L.)

by

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SIGNED: Richard Michael Kirkpatrick

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To all others who contributed in any way and are not mentioned here, the author is deeply grateful.
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<td>13</td>
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<td>16</td>
</tr>
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ABSTRACT

Experiments were conducted in 1970 at Tucson, Arizona, to study some effects of treated municipal wastewater on growth, yield, and quality of oats (Avena sativa L.) grown for pasture forage and grain.

When first and second pasture cuttings were combined no differences were noted between irrigation and fertilizer treatments or cultivars for plant height, tillers per plant, green forage production, and dry forage production. Generally, oat pasture grown with wastewater contained more protein than did forage grown with well water and suggested amounts of nitrogen, phosphorus, and potassium.

Oat grain data showed no differences between irrigation and fertilizer treatments for maturity, plant height, flower blasting, lodging, panicles per unit area, seeds per panicle, seed weight, yield, and protein. Cultivars responded similarly in grain production for flower blasting, lodging, seeds per panicle, and seed weight. Cultivars differed in grain maturity dates, plant height, panicles per unit area, yield, and protein content.

Treated municipal wastewater can be utilized to produce high yields of excellent quality oat pasture and grain for horses.
INTRODUCTION

Pollution is one of the most controversial subjects in the United States and throughout the world. The big question is what are we going to do with our waste products? To be even more specific—what is going to be done with treated municipal wastewater (sewage effluent)?

Because of the need to conserve diminishing water supplies, agriculture must either look for a way to control its present water supply or find new sources of water. Since it is difficult to control present water supplies, a new source would certainly be a blessing.

Treated municipal wastewater is high in the three principal fertilizer elements—nitrogen, phosphorus, and potassium. Therefore, it should provide a good source of irrigation water and plant nutrients for growing agricultural crops.

The primary objectives of this experiment were:

1. To determine the effect of treated municipal wastewater on the growth and yield of three oat cultivars.
2. To determine the effect of treated municipal wastewater on the protein content of forage and grain from three oat cultivars.
LITERATURE REVIEW

Methods of Treating Municipal Sewage

Sewage treatment plants are designed to reduce disease-promoting bacteria and stabilize municipal wastes without producing nuisance, odor, or endangering health (10, 13, 15). Escritt (10) pointed out that there are three methods of treatment: (a) on land, (b) in biological "filters," and (c) by the activated sludge processes. Land treatment consists of two methods: (a) land filtration and broad irrigation. Land filtration consists of diverting sewage into shallow trenches, from which it soaks into the soil. This process filters out suspended solids and leaves them on the soil surface. Broad irrigation is used on soils that will not permit adequate filtration. This method exposes sewage to air and permits oxidation (10).

Biological filters oxidize solids in sewage as it flows over surfaces covered with bacteria, other forms of micro-organisms, and forms of vegetable and animal life (10, 13).

The activated sludge process is one of the most widely used methods of treatment in the United States (30). Activated sludge is a floc consisting of bacteria, protozoa, and other micro-organisms in suspension. These micro-organisms feed on and break down the organic matter in
sewage. Aeration is necessary to provide oxygen for this process (10). A clear, sparkling, odor-free effluent is produced as a result of the activated sludge treatment (15, 23, 30).

**Uses for Treated Municipal Wastewater**

Gallagher (14) noted that the largest single use of treated municipal wastewater in industry is for cooling. In Texas, one of the state's largest petrochemical complexes has utilized treated municipal wastewater for cooling purposes for a number of years, and it has proved feasible and economical (12). Industry also uses wastewater as a reagent, constituent, solvent, and as a source of power in the production of steam (14). Symons (27) reported that industry will find it both desirable and necessary to make use of treated municipal wastewater.

Wastewater has been used as a source of irrigation water and plant nutrients to grow grass, shrubs, trees, and flowers for recreational purposes (19). Other recreational uses include ponds and lakes for boating, fishing, and swimming (2, 28). Weinberger and Stephan (29) reported that as sewage treatments are improved the liquid effluent will be too good to throw away. In South Lake Tahoe, California, treated municipal wastewater is of such quality that it is used for water contact sports and fish ponds (2).
Because of its high level of plant nutrients, treated municipal wastewater is now being used to irrigate many agricultural crops (11). Sagmuller and Sopper (24) reported increased terminal growth of 72% on white spruce trees when irrigated with sewage effluent. Farrell (11) also indicated successful use of treated municipal wastewater on forest trees. In a study by Murphey and Brisbin (22), increased growth was observed when red pine was irrigated with sewage effluent.

Kardos et al. (20) pointed out that increases of two to three tons per acre were achieved when hay was irrigated with sewage effluent. Increases of as much as 100 bushels per acre were obtained with its use on corn (20). Swope (26) noted that effluent promoted crop growth. He showed increases of 300% in hay yields, and 50% in corn yields. Farrell (11) observed increases in yields of hay, corn, and corn stover.

Studies by Day, Tucker, and Vavich (6) conducted at the Arizona Agriculture Experiment Station show conclusively that treated municipal wastewater can provide an efficient, practical, and inexpensive source of irrigation water for the production of small grains forage and grain. Heukelekian (17) reported that treated municipal wastewater was used to produce field crops in arid regions of Israel. Cattle have consumed treated municipal wastewater with no harmful effects (6, 21).
Swope (26) noted increases of 17 to 51% when oat grain was irrigated with sewage effluent. Oats produced 24 and 69% more pasture forage and grain respectively, when grown with treated municipal wastewater in Arizona (6).

Treated municipal wastewater is higher than well water in nitrogen, phosphorus, and potassium (9, 19). Hirsch (19) pointed out that the retail fertilizer value of reclaimed water, compared to commercial fertilizer was $18 per acre-foot. The average cost per acre-foot for treated municipal wastewater is less than one-half the cost of well water in Arizona (6). Dye (9) indicated that crops grown with treated municipal wastewater should be of superior quality. Increases in protein and digestible laboratory nutrients in barley pasture and wheat grain have been demonstrated (3, 8). Day (3) concluded that the milling and baking quality of wheat grown with sewage effluent was lower than that in wheat grown with conventional irrigation and fertilizer.

Day, Tucker, and Vavich (5) found some increase in protein content in oat grain irrigated with sewage effluent, but showed no increase in digestible laboratory nutrients. In another study with oat pasture forage an increase in protein was found, but there was a decrease in digestible laboratory nutrients (7).

The author was unable to find any reports in the literature relative to the effects of treated municipal
wastewater on the growth and quality of oat pasture forage and oat grain for use in horse nutrition.
MATERIALS AND METHODS

Two experiments were conducted at Tucson, Arizona, in 1970 to compare the pasture and grain production and quality of oats irrigated with treated municipal wastewater with the production and quality of oats irrigated with well water and fertilized with suggested amounts of commercial fertilizer (112, 37, and 0 kg/ha of nitrogen, phosphorus, and potassium, respectively). Wastewater treatment supplied nutrients at each irrigation; therefore nutrients were added to the well water at each irrigation.

Two irrigation and fertilizer treatments were used: (a) well water with suggested amounts of nitrogen (N), phosphorus (P), and potassium (K); and (b) treated municipal wastewater with no additional water or fertilizer. Approximately 748 m$^3$/ha (65,340 ft$^3$/acre) of irrigation water was required to grow two oat pasture cuttings. About 1498 m$^3$/ha (130,680 ft$^3$/acre) of irrigation water was required to produce oat grain. Three oat cultivars ('Markton,' 'Mesa,' and 'Palestine') were grown with each irrigation and fertilizer treatment. The experimental design was a split-plot, with irrigation and fertilizer treatments as main plots and cultivars as sub-plots, with four replications.

Treated municipal wastewater from the activated sludge sewage plant was used in this experiment. This
contained approximately 24, 9, and 11 ppm of N, P, and K, respectively. This was equivalent to 65, 22, and 27 pounds of N, P, and K respectively per acre-foot of wastewater. Two hundred eight-liter (55 gal) barrels, that had one end removed, were set in soil and used as pots in which to grow oat plants. The entire inside surface of the pots was sealed with asphalt tar to control moisture. Each pot had a surface area of 0.28 m$^2$ (3 ft$^2$) and a depth of 86 cm (34 in). Each pot contained 8 cm (3 in) of crushed rock at the bottom and 71 cm (28 in) of Comoro sandy loam soil which had a field capacity of 11.2% and a permanent wilting point of 4.8%. The entire research area was completely covered with 3 cm (1 in) mesh poultry netting for rodent and bird control.

Forty-eight seeds were planted in each pot on February 8, 1970 (56 kg/ha). On February 17, 1970 the plants were thinned to 36 plants per pot (211,700 plants per hectare). Each pot was pre-irrigated to bring the soil moisture up to field capacity prior to planting. After planting, when 65% of the available soil moisture was used (based on soil moisture tests), the pots were irrigated to bring the soil moisture up to field capacity. This procedure was followed throughout the growing season.

The first pasture forage cutting was made at the jointing stage of plant growth on April 28, 1970. The second cutting occurred on May 22, 1970. Both cuttings were harvested by hand at 8 cm above the soil level.
following data were obtained for each cutting: plant height, tillers per plant, green forage yield, dry forage yield, and total protein.

At maturity, the grain was harvested and the following data were obtained: days from planting to maturity, plant height, flower blasting, lodging, panicles per unit area, seeds per panicle, seed weight, grain yield, and total protein.

Total protein in both pasture forage and grain was determined using the micro-kjeldahl method (1). All data were analyzed using the standard analysis of variance and means were compared using Student-Newman-Keul's test as described by Steel and Torrie (25).
RESULTS AND DISCUSSION

Average plant heights for the first cutting, second cutting, and combined first and second cuttings of oat pasture forage for the two irrigation and fertilizer treatments and three cultivars are reported in Tables 1, 2, and 3. There were no differences in plant heights between irrigation and fertilizer treatments and cultivars.

The first cutting of pasture forage had more tillers per plant when grown with well water and suggested N, P, and K than when grown with wastewater with no additional water or fertilizer (Table 1). The reverse was true for the second cutting (Table 2). When the two cuttings were combined there were no differences in tillers per plant between treatments (Table 3). No differences in tillers per plant were observed between cultivars (Tables 1, 2, and 3). Wastewater appeared to decrease germination and early tiller development. This observation was also made by Hinesly and Sosewitz (18) when plants were grown with digested sludge. A partial explanation may be that there were higher concentrations of ammonium and ammonia ions in wastewater than in well water with suggested N, P, and K. After establishment, oat plants produced more tillers when grown with wastewater, because more plant nutrients were available.
Table 1. Average plant height, tillers per plant, green forage, oven-dry forage, and total protein from the first cutting of pasture forage for Markton, Mesa, and Palestine oats grown in Comoro sandy loam soil with different irrigation and fertilizer treatments at Tucson, Arizona in 1970.

<table>
<thead>
<tr>
<th>Irrigation and fertilizer treatment</th>
<th>Cultivar</th>
<th>Plant height (cm)</th>
<th>Tillers per plant (no.)</th>
<th>Green forage in 0.28 m² (g)</th>
<th>Dry forage in 0.28 m² (g)</th>
<th>Total protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well water + suggested N, P, K</td>
<td>Markton</td>
<td>57 a</td>
<td>10 a</td>
<td>574 a</td>
<td>111 ab</td>
<td>26 a</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>56 a</td>
<td>9 a</td>
<td>606 a</td>
<td>119 b</td>
<td>25 a</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>55 a</td>
<td>10 a</td>
<td>619 a</td>
<td>121 b</td>
<td>24 a</td>
</tr>
<tr>
<td>Wastewater with no additional water or fertilizer</td>
<td>Markton</td>
<td>56 a</td>
<td>9 a</td>
<td>596 a</td>
<td>91 a</td>
<td>28 a</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>54 a</td>
<td>7 a</td>
<td>592 a</td>
<td>98 ab</td>
<td>27 a</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>50 a</td>
<td>9 a</td>
<td>546 a</td>
<td>103 ab</td>
<td>23 a</td>
</tr>
</tbody>
</table>

Significance of differences:
- Between treatments: ns, * ns, ** ns

Coefficient of Variation (%):
- Treatments: 4 8 8 7 6
- Cultivars: 4 15 8 6 5

Means followed by the same letter are not different at the 5% level of significance.

Legend: ** = 1%, * = 5%, ns = not significant.
Table 2. Average plant height, tillers per plant, green forage, oven-dry forage, and total protein from the second cutting of pasture forage for Markton, Mesa, and Palestine oats grown in Comoro sandy loam soil with different irrigation and fertilizer treatments at Tucson, Arizona in 1970.

<table>
<thead>
<tr>
<th>Irrigation and fertilizer treatment</th>
<th>Cultivar</th>
<th>Plant height (cm)</th>
<th>Tillers (no.)</th>
<th>Green forage in 0.28 m² (g)</th>
<th>Dry forage in 0.28 m² (g)</th>
<th>Total protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well water + suggested N, P, K</td>
<td>Markton</td>
<td>49 a</td>
<td>5 a</td>
<td>161 a</td>
<td>46 a</td>
<td>19 a</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>51 a</td>
<td>5 a</td>
<td>201 a</td>
<td>63 a</td>
<td>20 a</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>47 a</td>
<td>6 a</td>
<td>189 a</td>
<td>58 a</td>
<td>18 a</td>
</tr>
<tr>
<td>Wastewater with no additional water or fertilizer</td>
<td>Markton</td>
<td>51 a</td>
<td>7 a</td>
<td>237 a</td>
<td>61 a</td>
<td>21 a</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>53 a</td>
<td>7 a</td>
<td>203 a</td>
<td>67 a</td>
<td>22 a</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>46 a</td>
<td>8 a</td>
<td>187 a</td>
<td>59 a</td>
<td>19 a</td>
</tr>
</tbody>
</table>

Significance of differences:
- Between treatments: ns ** ns ns *

Coefficient of Variation (%):
- Treatments: 10 7 16 14 6
- Cultivars: 7 16 17 18 6

Means followed by the same letter are not different at the 5% level of significance.

Legend: ** = 1%, * = 5%, ns = not significant.
Table 3. Average plant height, tillers per plant, green forage, oven-dry forage, and total protein from the first and second cuttings of pasture forage for Markton, Mesa, and Palestine oats grown in Comoro sandy loam soil with different irrigation and fertilizer treatments at Tucson, Arizona in 1970.

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<tr>
<th>Irrigation and fertilizer treatment</th>
<th>Cultivar</th>
<th>Plant height (cm)</th>
<th>Tillers per plant (no.)</th>
<th>Green forage in 0.28 m² (g)</th>
<th>Dry forage in 0.28 m² (g)</th>
<th>Total protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well water + suggested N, P, K</td>
<td>Markton</td>
<td>54 a</td>
<td>7 a</td>
<td>368 a</td>
<td>79 a</td>
<td>22 a</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>54 a</td>
<td>7 a</td>
<td>404 a</td>
<td>91 a</td>
<td>23 a</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>51 a</td>
<td>8 a</td>
<td>405 a</td>
<td>90 a</td>
<td>21 a</td>
</tr>
<tr>
<td>Wastewater with no additional water</td>
<td>Markton</td>
<td>54 a</td>
<td>8 a</td>
<td>417 a</td>
<td>76 a</td>
<td>25 b</td>
</tr>
<tr>
<td>or fertilizer</td>
<td>Mesa</td>
<td>54 a</td>
<td>7 a</td>
<td>398 a</td>
<td>83 a</td>
<td>25 b</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>48 a</td>
<td>9 a</td>
<td>367 a</td>
<td>81 a</td>
<td>21 a</td>
</tr>
</tbody>
</table>

Significance of differences: Between treatments ns ns ns ns *

Coefficients of Variation (%): Treatments 7 7 10 7 3 Cultivars 4 13 4 8 3

Means followed by the same letter are not different at the 5% level of significance.

Legend: ** = 1%, * = 5%, ns = not significant.
With one exception oats produced similar amounts of green and dry pasture forage when grown with well water and suggested N, P, and K as when grown with wastewater with no additional water or fertilizer (Tables 1, 2, and 3). In the first cutting Markton produced less dry forage when grown with wastewater than did Mesa and Palestine grown with well water and suggested N, P, and K (Table 1). Average green and dry forage production for cultivars grown with well water were 600 and 117 grams per unit area, respectively. Cultivars grown with wastewater averaged 578 and 97 grams of green and dry forage per unit area, respectively. Generally, when the first and second cuttings were combined, wastewater produced forage with higher moisture and lower dry matter content than did well water plus N, P, and K (Table 3).

First cutting pasture forage contained similar amounts of protein for both irrigation and fertilizer treatments and all cultivars (Table 1). Second cutting pasture forage produced with wastewater contained more protein than forage grown with well water and suggested N, P, and K (Table 2). This may be explained by the fact that more tillers per plant were produced with wastewater, which resulted in forage with a higher leaf to stem ratio.

When the two cuttings were combined, forage grown with wastewater contained more protein than forage grown with well water with suggested N, P, and K (Table 3).
Except for Palestine, cultivars grown with wastewater produced forage containing more protein than did forage grown with well water with suggested N, P, and K (Table 3).

Oats provide excellent pasture forage for horses. When horses are pastured on oats there is less danger from bloat and prussic acid poisoning than when they are grazed on many other forage crops. In semi-arid regions of the world, oats make popular winter pasture for mares in foal, because green forage is high in vitamin A, which is necessary for reproduction. In a study by Day, Tucker, and Vavich (4), oats pasture forage grown with wastewater did not accumulate enough nitrate to be unsafe for livestock feed.

Since oats forage from the first cutting contained more protein than forage from the second cutting, it provided feed with a higher nutritional value. Hershberger, Merritt, and Darlington (16) also reported that early harvested forages were best for horses in Pennsylvania.

The average number of days from planting to maturity were similar for oats grown with the two irrigation and fertilizer treatments (Table 4). Markton required more time from planting to maturity than did the other two cultivars. In areas where a short season oat is desired, Mesa or Palestine would be preferred over Markton.

Oats had similar plant heights for both treatments (Table 4). Palestine was shorter than the other two cultivars, and Mesa was shorter than Markton when grown with
Table 4. Average number of days from planting to maturity, plant height, flower
blasting, lodging, panicles per unit area, seeds per panicle, seed
weight, grain yield, and total protein in grain from Markton, Mesa, and
Palestine oats grown in Comoro sandy loam soil with different irrigation
and fertilizer treatments at Tucson, Arizona in 1970.

<table>
<thead>
<tr>
<th>Irrigation and fertilizer treatment</th>
<th>Cultivar</th>
<th>Planting to maturity (days)</th>
<th>Plant height (cm)</th>
<th>Flower blasting (%)</th>
<th>Lodging (%)</th>
<th>Panicles in 0.28 m² (no.)</th>
<th>Seeds per panicle (no.)</th>
<th>Weight of 1000 seeds (g)</th>
<th>Grain yield in 0.28 m² (g)</th>
<th>Total protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well water + suggested N, P, K</td>
<td>Markton</td>
<td>120 b</td>
<td>73 c</td>
<td>33 a</td>
<td>43 a</td>
<td>65 a</td>
<td>2 a</td>
<td>13 a</td>
<td>2 a</td>
<td>21 ab</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>113 a</td>
<td>56 b</td>
<td>2 a</td>
<td>75 a</td>
<td>161 ab</td>
<td>3 a</td>
<td>19 a</td>
<td>8 a</td>
<td>26 c</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>114 a</td>
<td>47 a</td>
<td>5 a</td>
<td>24 a</td>
<td>183 b</td>
<td>10 a</td>
<td>25 a</td>
<td>41 b</td>
<td>19 a</td>
</tr>
<tr>
<td>Wastewater with no additional water or fertilizer</td>
<td>Markton</td>
<td>122 b</td>
<td>68 c</td>
<td>46 a</td>
<td>38 a</td>
<td>71 a</td>
<td>5 a</td>
<td>13 a</td>
<td>5 a</td>
<td>23 b</td>
</tr>
<tr>
<td></td>
<td>Mesa</td>
<td>112 a</td>
<td>65 c</td>
<td>3 a</td>
<td>92 a</td>
<td>143 ab</td>
<td>3 a</td>
<td>14 a</td>
<td>6 a</td>
<td>28 c</td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>113 a</td>
<td>49 a</td>
<td>6 a</td>
<td>41 a</td>
<td>205 b</td>
<td>11 a</td>
<td>20 a</td>
<td>41 b</td>
<td>19 a</td>
</tr>
</tbody>
</table>

Significance of differences:

| Between treatments | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

Coefficient of Variation (%):

| Treatments | 1  | 2  | 123| 34 | 30 | 35 | 29 | 28 | 4  |
| Cultivars  | 1  | 5  | 88 | 43 | 16 | 51 | 9  | 39 | 5  |

Means followed by the same letter are not different at the 5% level of significance.

Legend: ** = 1%, * = 5%, ns = not significant.
well water and suggested N, P, and K. In areas where straw is desired for bedding Markton and Mesa would produce more bedding than Palestine.

No significant differences in flower blasting were observed between treatments and between cultivars (Table 4). Although flower blasting was higher for Markton than for the other cultivars, high coefficients of variation for treatments and cultivars prevented this from being statistically significant.

Lodging at maturity was similar for both treatments and cultivars (Table 4). Under the conditions of this experiment oats grown with wastewater did not lodge any more than oats grown in the conventional manner.

Number of panicles per unit area for oats grown with both irrigation and fertilizer treatments were not different (Table 4). However, differences did occur between cultivars. Palestine had more panicles per unit area than Markton. These data indicate that Palestine tillers more profusely than Markton. This suggests that Palestine may be planted at a lower rate than would be necessary for Markton.

No significant differences in seeds per panicle or seed weight were observed between treatments or cultivars (Table 4). These observations suggest that oats grown with wastewater are as desirable for grain production as oats produced with well water and suggested N, P, and K.
Oats grown with both treatments had similar grain yields (Table 4). This indicates that under field conditions no significant yield reductions would be expected with wastewater. Palestine was more productive than Markton or Mesa, in both treatments. Palestine would be superior to the other two cultivars where grain quantity was the main objective.

Table 4 gives the average protein in oat grain grown with well water and suggested amounts of N, P, and K, and with wastewater. No differences in grain protein were observed between treatments. Mesa produced higher protein grain than Markton or Palestine with both treatments. When wastewater was used for irrigation, Markton produced grain that had a higher protein content than did grain from Palestine. High protein grain is essential for young horses, because their protein requirements are highest during the early stages of growth and development. High protein grain is equally important for gestating mares for the developing fetus. During the breeding season, it is a general practice to feed stallions high protein rations to increase their breeding efficiency.
SUMMARY

Two experiments were conducted in 1970 at Tucson, Arizona, to study some effects of treated municipal wastewater on growth, yield, and quality of forage and grain from oats.

In the first cutting, oat pasture irrigated with wastewater performed as well as pasture irrigated with well water and suggested amounts of N, P, and K in plant height, green forage production, and protein content. The foregoing also was true for cultivars. Pasture grown with well water and suggested N, P, and K produced more tillers per plant and more dry forage than pasture grown with wastewater.

Oat pasture in the second cutting showed no differences in plant height, green forage, and dry forage between treatments and cultivars. Wastewater increased tiller number and forage protein in the second cutting.

When first and second cuttings were combined no differences were observed between treatments and cultivars for plant height, tillers per plant, green forage weight, and dry forage weight. Except for Palestine, oat pasture grown with wastewater contained more protein than did forage grown with well water and suggested N, P, and K.

Oats grown for grain showed no differences between irrigation and fertilizer treatments for maturity, plant
height, flower blasting, lodging, panicles per unit area, seeds per panicle, seed weight, yield, and protein. In grain production, cultivars responded similarly for flower blasting, lodging, seeds per panicle, and seed weight. When grown for grain Markton was later in maturity than Mesa or Palestine, taller, had fewer panicles per unit area, and produced less grain than Palestine. When grown with wastewater Markton and Mesa contained more protein than Palestine, and Mesa contained more protein than Markton.

Results from these experiments indicated that treated municipal wastewater can be efficiently utilized to produce high yields of superior quality pasture and grain from oats.
LITERATURE CITED


