# Preplant and Postemergence Herbicide Systems in Wyoming Sugarbeet

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## ABSTRACT

**Field studies were conducted in 1994 at two locations in northwest Wyoming and two locations in southeast Wyoming to examine sugarbeet (*Beta vulgaris* L.) weed management systems. Twelve systems were established including three preplant options (full-rate, one-half-rate and no-preplant herbicide) followed by postemergence applications, including either early-post, two-post, or three-post treatments, as well as a later season full-post treatment. Preplant followed by postemergence treatments controlled weeds effectively at all locations. Field sites in northwest Wyoming had relatively high weed populations and the most economical practices were generally associated with three herbicide applications. Average weed populations were lower in southeast Wyoming and least-cost treatments usually involved two applications. Labor was a larger component of aggregate herbicide and labor costs at sites in northwest Wyoming. Doubling the labor rate from $6 to $12/hr had a more significant impact in generating higher overall costs across all twelve treatments for northwest Wyoming sites than for southeast sites. Ranking of treatments with respect to total herbicide and labor costs changed very little with a doubling of the wage rate. At both wage rates, double postemergence systems were more economical than either one early-post or one later season full-post system.**

**Additional Key Words:** *Beta vulgaris* L., herbicides, hand labor, weed control costs

Weed free sugarbeet production (*Beta vulgaris* L.) is critical for profitability. Sugarbeet producers use a combination of mechanical, manual hoeing, and chemical weed control methods. In Wyoming, herbicides are applied to over 95% of fields prior to planting, and 60% of the fields are sprayed after planting (Legg et. al. 1992). Careful herbicide selection can significantly reduce weed control costs, however, overall cost reductions will be achieved only if the cost savings from reduced hand labor and weed populations offset the added cost of purchasing and applying more herbicide. Excellent weed control can often be obtained with preplant incorporated followed by postemergence herbicide treatments (Miller and Fornstrom 1988 and 1989; Wicks and Wilson 1983; Winter and Wiese 1982). Previous studies have not emphasized the effectiveness of multiple postemergence weed management systems. The purpose of this research was to examine the cost effectiveness of single preplant or postemergence systems, as well as multiple postemergence weed management programs having different proportions of hand labor and herbicide.

## MATERIALS AND METHODS

Field trials were conducted in the summer of 1994 at four locations in Wyoming: the Powell Research and Extension Center and a cooperator's farm near Worland (both in northwest Wyoming); and the Torrington Research and Extension Center and a cooperator's farm near Wheatland (both in southeast Wyoming). Twelve management systems were established in a split-plot randomized complete block design with four replicates (Table 1). The three main plots included no-preplant (none); one-half-preplant (½-rate); and full-preplant (full-rate) herbicide.

Each of these three preplant blocks was split to include postemergence applications of: one early post treatment (early-post) applied to cotyledonary sugarbeet (#2, #6 and #10); two post treatments (double-post) applied to cotyledonary sugarbeet and 7 days after the cotyledonary stage (#3, #7 and #11); and three post treatments (triple-post) applied to cotyledonary sugarbeet, 7 days later and 14 days after the cotyledonary stage (#4, #8 and #12). In addition, when no preplant herbicide was applied, a single total-postemergence treatment (full-post, #1) was applied 14 days after the cotyledonary stage. Also, a no-post (preplant only) herbicide treatment was added to the one-half and full-rate preplant blocks (#5 and #9). Dates and rates of herbicide associated with these treatments are shown by location in Table 2.

**Table 1.** Treatments, chemistry, active ingredient, and price of herbicides utilized in study.

| Treatment Designation | Combinations: Preplant | Combinations: Postemergence |
|---|---|---|
| #1 | none | full-post |
| #2 | none | early-post |
| #3 | none | double-post |
| #4 | none | triple-post |
| #5 | ½-rate | none |
| #6 | ½-rate | early-post |
| #7 | ½-rate | double-post |
| #8 | ½-rate | triple-post |
| #9 | full-rate | none |
| #10 | full-rate | early-post |
| #11 | full-rate | double-post |
| #12 | full-rate | triple-post |

| Herbicides | Chemistry | Price | Active Ingredient |
|---|---|---|---|
| cycloate | S-ethyl cyclohexylethylcarbamothioate | $13.34/l | 719g/l |
| ethofumesate | (±)-2-[4-[(6-chloro-2-benzoxazolyl)oxy] phenoxy] propanoic acid | $39.59/l | 479g/l |
| clopyralid | 3,6-dichloro-2-pyridinecarboxylic acid | $117.55/l | 359g/l |
| desmedipham + phenmedipham | ethyl [3-[[(phenylamino) carbonyl] oxy] phenyl]carbamate + 3-[(methoxycar-bonyl) amino] phenyl (3-methylphenyl) carbamate | $22.97/l | 156g/l |
| sethoxydim | 2-[1-(ethoxyimino) butyl]-5-[2-(ethyl-thio) propyl]-3-hydroxy-2-cyclohexen--1-one | $27.56/l | 180g/l |
| triflusulfuron | methyl 2-[[[[[4-(dimethylamino)-6-(2,-2,2-trifluoroethoxy)-1,3,5-triazin-2-yl] amino] carbonyl] amino] sulfonyl]-3--methylbenzoate | $0.88/g | 50% |

**Table 2.** Dates and rates of preplant and postemergence herbicides by location.

| | Northwest Wyoming | | | | | | | | Southeast Wyoming | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | | Worland | | | | Torrington | | | | Wheatland | | | |
| Herbicide Treatments | Apr 24 | May 10 | May 17 | May 24 | Apr 21 | May 10 | May 17 | May 24 | Apr 14 | May 9 | May 16 | May 23 | Apr 15 | May 11 | May 18 | May 24 |
| | gai/ha | | | | gai/ha | | | | gai/ha | | | | gai/ha | | | |
| Preplant | | | | | | | | | | | | | | | | |
| cycloate | 2800 | — | — | — | — | — | — | — | 2240 | — | — | — | — | — | — | — |
| ethofumesate | — | — | — | — | 2240 | — | — | — | — | — | — | — | 1680 | — | — | — |
| Early-Post | | | | | | | | | | | | | | | | |
| desm-phen | — | 370 | — | — | — | 370 | — | — | — | 370 | — | — | — | 370 | — | — |
| clopyralid | — | 105 | — | — | — | 105 | — | — | — | 105 | — | — | — | 105 | — | — |
| ethofumesate | — | 90 | — | — | — | 90 | — | — | — | — | — | — | — | 90 | — | — |
| sethoxydim | — | 224 | — | — | — | 224 | — | — | — | — | — | — | — | — | — | — |
| triflusulfuron | — | 18 | — | — | — | 18 | — | — | — | — | — | — | — | — | — | — |
| oil-conc. (l/ha) | — | 2.5 | — | — | — | 2.5 | — | — | — | — | — | — | — | — | — | — |
| Double-Post | | | | | | | | | | | | | | | | |
| desm-phen | — | 370 | 370 | — | — | 370 | 370 | — | — | 370 | 370 | — | — | 370 | — | — |
| clopyralid | — | 105 | 105 | — | — | 105 | 105 | — | — | 105 | — | — | — | 105 | — | — |
| ethofumesate | — | 90 | — | — | — | 90 | — | — | — | — | — | — | — | 90 | — | — |
| sethoxydim | — | 224 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| triflusulfuron | — | 18 | 18 | — | — | 18 | — | — | — | — | — | — | — | — | — | — |
| oil-conc. (l/ha) | — | 2.5 | — | — | — | 2.5 | — | — | — | — | — | — | — | — | — | — |

**Table 2** *(Continued).* Dates and rates of preplant and postemergence herbicides by location.

| | Northwest Wyoming | | | | | | | | Southeast Wyoming | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | | Worland | | | | Torrington | | | | Wheatland | | | |
| Herbicide Treatments | Apr 24 | May 10 | May 17 | May 24 | Apr 21 | May 10 | May 17 | May 24 | Apr 14 | May 9 | May 16 | May 23 | Apr 15 | May 11 | May 18 | May 24 |
| | gai/ha | | | | gai/ha | | | | gai/ha | | | | gai/ha | | | |
| Triple-Post | | | | | | | | | | | | | | | | |
| desm-phen | — | 180 | 280 | 280 | — | 180 | 280 | 280 | — | 180 | 280 | 280 | — | 180 | 280 | 280 |
| clopyralid | — | 105 | 105 | 105 | — | 105 | 105 | — | — | 105 | — | — | — | 105 | — | — |
| ethofumesate | — | 90 | — | — | — | 90 | — | — | — | — | — | — | — | 90 | — | — |
| sethoxydim | — | 224 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| triflusulfuron | — | 18 | — | — | — | 18 | — | — | — | — | — | — | — | — | — | — |
| oil-conc. (l/ha) | — | 2.5 | — | — | — | 2.5 | — | — | — | — | — | — | — | — | — | — |
| Full-Post | | | | | | | | | | | | | | | | |
| desm-phen | — | — | — | 740 | — | — | — | 740 | — | — | — | 740 | — | — | — | 740 |
| clopyralid | — | — | — | 210 | — | — | — | 210 | — | — | — | 210 | — | — | — | 210 |
| ethofumesate | — | — | — | 100 | — | — | — | 100 | — | — | — | — | — | — | — | — |
| sethoxydim | — | — | — | 224 | — | — | — | — | — | — | — | 224 | — | — | — | 224 |
| oil-conc. (l/ha) | — | — | — | 2.5 | — | — | — | — | — | — | — | — | — | — | — | — |

Field experiments were managed as follows. In northwest Wyoming, field site plots were 3.3 by 22.8 m (11 by 75 ft) with a Garland clay loam soil (fine, mixed mesic, Typic Haplargid) at Powell; and plots at Worland were 3.3 by 21.9 m (11 by 72 ft) with a Lostwell clay loam soil (fine-loamy, mixed, Mesic Typic Torrifluvent). In southeast Wyoming, field site plots at Torrington were 3 by 9.1 m (10 by 30 ft) with a Bayard fine sandy loam soil (coarse, loamy; mixed, Mesic, Torriorthenic, Haplustoll); and at Wheatland plots measured 3 by 22.8 m (10 by 75 ft) with a Buffcreek sandy loam soil (loamy skeletal, mixed, Mesic, Ustic Haplocalcid).

In northwest Wyoming, sugarbeet (var. Hilleshog MonoHy R2) was planted to stand at a rate of 138,320 seeds/ha (56,000 seeds/A) in 56 cm (22 inch) rows on April 21 (Powell) and April 18 (Worland). In southeast Wyoming, sugarbeet (var. Monohikari) was planted to stand at a rate of 167,960 seeds/ha (68,000 seeds/A) in 76 cm (30 inch) rows on April 14 (Torrington) and April 13 (Wheatland). Herbicide application dates and corresponding growth stages for sugarbeet and weeds are summarized by location in Table 3.

Herbicide treatments and rates were not the same at all sites. Cycloate, which requires almost immediate incorporation, was applied at both station sites, while ethofumesate, which can be applied without incorporation, was applied at both off-station sites because of availability and lack of availability of incorporation equipment, respectively. Further, post herbicide treatments differed at each site. Inclusion or exclusion of the various herbicides was based on predominant weed species present in each field site at the time of application, and treatments were not designed to be similar across sites. All herbicide treatments were applied in a band to one-third the area. All locations were cultivated with a row crop cultivator to remove weeds between the rows and to prepare the plots for irrigation.

Weeds in the study site locations included redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Chenopodium album* L.), wild buckwheat (*Polygonum convolvulus* L.), hairy nightshade (*Solanum sarrachoides* Sendtner), black nightshade (*Solanum nigrum* L.), redstem filaree (*Erodium cicutarium* (L.) L'Her. ex Ait.), wild mustard (*Sinapis arvensis* L.), Russian thistle (*Salsola iberica* Sennen & Pau), kochia (*Kochia scoparia* (L.) Schrad.), common sunflower (*Helianthus annuus* L.), green foxtail (*Setaria viridis* (L.) Beauv.) and wild oat (*Avena fatua* L.). The predominant weed species were wild mustard and redstem filaree at Powell; black nightshade and redroot pigweed at Worland; hairy nightshade and common lambsquarters at Torrington; and wild buckwheat and redroot pigweed at Wheatland.

**Table 3.** Herbicide application dates with corresponding sugarbeet and weed growth stages by location.

| | Northwest Wyoming | | | | | | Southeast Wyoming | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | Worland | | | Torrington | | | Wheatland | | |
| Herbicide Applications | Date | Beets | Weeds | Date | Beets | Weeds | Date | Beets | Weeds | Date | Beets | Weeds |
| Preplant | April 21 | — | — | April 21 | — | — | April 14 | — | — | April 15 | — | — |
| First Post | May 10 | coty | 0.5-3.8 cm | May 10 | coty | 1.3 cm | May 9 | replant | 1.3 cm | May 11 | coty | 1.3-2.5 cm |
| Second Post | May 17 | 2 lf | 0.6-2.5 cm | May 17 | 2 lf | 1.3-2.5 cm | May 16 | coty-2 lf | 1.3-2.5 cm | May 18 | 2 lf | 2.5 cm |
| Third Post | May 24 | 4-6 lf | 2.5-5.1 cm | May 24 | 4-6 lf | 2.5 cm | May 23 | coty-4 lf | 2.5 cm | May 24 | 4 lf | 2.5-3.8 cm |

In early June, weed populations were counted and hoeing time recorded at each location to derive per hectare labor requirements for each of the twelve treatments (Table 4). Weed populations and hoeing times (and resulting labor costs) were statistically different among treatments at each field site.

Economic analysis for this study was based on comparing aggregate herbicide and labor costs among treatments. With the observed herbicide rates (Table 2) and hoeing times (Table 4), partial sugarbeet cost budgets were prepared for all 12 treatments by location to derive the following: (1) a charge for herbicide associated with each treatment based on respective rates, band application and 1994 prices; (2) a charge for incorporating and/or applying herbicide, based on 1994 custom rates of $12.71/ha ($5.15/A) for preplant incorporation and $8.57/ha($3.47/A) for post emergence application as reported by Hewlett and Munsell (1994); (3) hoeing labor associated with each treatment at a standard rate of $6/hr based on average hourly rates for field workers, excluding housing and meals (USDA-NASS 1994); and (4) interest on operating capital (required for abovementioned costs) computed at an annual rate of 6% on a pro-rated basis for the number of months such costs were committed over the year based on similar assumptions used by the U.S.D.A. for estimating costs (USDA-ERS 1994).

## RESULTS

Hoeing labor was directly related to weed population ($R^2$=0.930). The average time to walk a sugar beet field was 5.6 hr/ha (2.25 hr/A) and weeding required an additional 0.5 hr/ha (0.19 hr/A) for every 2,470 weeds/ha (1000 weeds/A). Table 5 shows that weed populations and associated hoeing times (averaged across all 12 treatments) were considerably higher in northwest Wyoming (Powell and Worland) compared to southeast Wyoming (Torrington and Wheatland); and both variables were statistically different among the four locations. Observing higher weed populations at Powell versus Torrington is consistent with earlier studies at these locations (Miller et al. 1992). Yield and revenue differences were not statistically different among treatments, since all treatments were weed free after hoeing (Table 5).

Herbicide and labor costs for each of the twelve treatments are summarized by location in Table 6. At both sites in northwest Wyoming, the most cost effective treatments were multiple applications spreading herbicide over a wider spectrum of time to better control weeds emerging at different stages e.g. #11 (preplant + double-post)

**Table 4.** Weed populations and resulting hoe time (labor) associated with alternative herbicide treatments by location.

| | Northwest Wyoming | | | | Southeast Wyoming | | | |
|---|---|---|---|---|---|---|---|---|
| | Powell | | Worland | | Torrington | | Wheatland | |
| Herbicide Treatments | Weeds | Labor | Weeds | Labor | Weeds | Labor | Weeds | Labor |
| | 1000 pl/ha | hr/ha | 1000 pl/ha | hr/ha | 1000 pl/ha | hr/ha | 1000 pl/ha | hr/ha |
| 1. No-preplant + full-post | 149.7 | 21.7 | 233.4 | 53.6 | 93.1 | 16.5 | 52.4 | 14.6 |
| 2. No-preplant + early-post | 138.6 | 35.1 | 149.7 | 38.8 | 69.4 | 13.3 | 54.3 | 13.6 |
| 3. No-preplant + double-post | 30.1 | 18.0 | 4.5 | 8.9 | 13.1 | 7.3 | 46.9 | 11.4 |
| 4. No-preplant + triple-post | 18.5 | 11.9 | 20.5 | 9.4 | 4.7 | 6.7 | 37.1 | 10.1 |
| 5. ½-preplant + no-post | 137.1 | 35.6 | 321.3 | 63.2 | 13.1 | 9.6 | 50.1 | 14.6 |
| 6. ½-preplant + early-post | 76.3 | 24.9 | 65.2 | 19.8 | 12.4 | 7.2 | 34.3 | 9.1 |
| 7. ½-preplant + double-post | 22.7 | 14.1 | 19.0 | 7.2 | 1.2 | 5.2 | 15.6 | 7.7 |
| 8. ½-preplant + triple-post | 7.4 | 10.6 | 5.9 | 6.2 | 1.7 | 5.7 | 7.7 | 6.7 |
| 9. full-preplant + no-post | 110.9 | 34.3 | 247.2 | 56.6 | 12.8 | 8.2 | 14.1 | 7.9 |
| 10. full-preplant + early-post | 55.1 | 20.7 | 77.8 | 18.8 | 2.2 | 5.7 | 4.9 | 6.2 |
| 11. full-preplant + double-post | 17.8 | 10.4 | 1.5 | 6.4 | 0.5 | 5.4 | 3.2 | 5.4 |
| 12. full-preplant + triple-post | 11.1 | 9.9 | 6.7 | 6.4 | 0.0 | 5.2 | 1.0 | 4.9 |
| LSD (0.05) | 23.8 | 4.0 | 28.8 | 7.2 | 9.3 | 1.1 | 9.9 | 1.1 |
| Mean | 64.5 | 20.5 | 96.1 | 24.7 | 18.8 | 7.9 | 26.7 | 9.4 |

**Table 5.** Weed control, hoeing time and sugarbeet response to weed management systems, all locations.

| | | | Sugarbeet | | | | |
|---|---|---|---|---|---|---|---|
| Comparison | Weeds | Hoeing Time | Initial | Harvest | Yield | Sucrose | Gross Return |
| | 1000 pl/ha | hr/ha | —1000 pl/ha— | | Mg/ha | % | $/ha |
| Location: | | | | | | | |
| Powell | 64.5 | 20.5 | 84.2 | 69.2 | 45.0 | 15.9 | 1771 |
| Worland | 96.1 | 24.7 | 75.3 | —— | —— | —— | —— |
| Torrington | 18.8 | 7.9 | 60.3 | 55.3 | 52.9 | 15.2 | 1946 |
| Wheatland | 26.7 | 9.4 | 61.2 | 45.2 | 33.4 | 17.6 | 1499 |
| LSD (0.05) | 8.8 | 1.6 | 2.7 | 4.1 | 2.1 | 0.5 | 67 |
| Preplant x post | | | | | | | |
| 1. None x full | 132.1 | 26.7 | 69.7 | 52.9 | 40.8 | 16.0 | 1600 |
| 2. None x early | 103.0 | 25.2 | 71.6 | 52.6 | 39.9 | 16.4 | 1633 |
| 3. None x double | 23.5 | 11.6 | 69.2 | 53.6 | 43.2 | 16.3 | 1756 |
| 4. None x triple | 20.3 | 9.6 | 69.2 | 49.4 | 44.1 | 16.1 | 1753 |
| 5. ½ x none | 130.4 | 30.6 | 72.1 | 62.7 | 43.5 | 16.3 | 1764 |
| 6. ½ x early | 47.2 | 15.3 | 68.7 | 60.8 | 46.4 | 16.3 | 1877 |
| 7. ½ x double | 14.6 | 8.4 | 68.2 | 56.8 | 43.5 | 16.3 | 1756 |
| 8. ½ x triple | 5.7 | 7.4 | 70.4 | 59.8 | 44.6 | 16.3 | 1796 |
| 9. full x none | 96.3 | 26.7 | 73.1 | 55.6 | 43.7 | 16.4 | 1778 |
| 10. full x early | 35.1 | 12.8 | 68.2 | 51.4 | 41.9 | 16.3 | 1699 |
| 11. full x double | 5.7 | 6.9 | 69.4 | 56.1 | 44.6 | 16.1 | 1768 |
| 12. full x triple | 4.7 | 6.7 | 73.1 | 64.7 | 49.1 | 16.4 | 2011 |
| LSD (0.05) | 9.7 | 2.0 | NS | 3.7 | NS | NS | NS |
| Loca. * Treat.: | | | | | | | |
| LSD (0.05) | 1.9 | 4.0 | NS | NS | NS | NS | NS |
| Mean | 51.6 | 15.6 | 70.2 | 56.4 | 43.8 | 16.3 | 1766 |

and #4 (triple-post). Multiple applications were more cost effective since the added cost of extra herbicide was more than offset by savings in labor. Conversely, high-cost treatments were those associated with poorer performance of early season herbicide (e.g. #2, early-post; #5, 1/2 preplant only; #6, 1/2 preplant + early-post and #9, preplant only). This resulted in much higher labor costs at later sugarbeet growth stages. Furthermore, labor ranged from 64% to 91% of the total cost, for early season treatments. The full-post treatment (#1) also proved to be costly in terms of both labor and herbicide.

In southeast Wyoming, inexpensive options were associated with early season treatments at both sites, i.e. preplant treatments only (#5 and #9) or preplant treatments with early-post (#6 and #10). Cost differences at these sites were more a result of herbicide as opposed to labor, given lower weed densities in southeast Wyoming. Multiple late season treatments were more costly since small labor savings (resulting from lower weed pressure) were simply inadequate to cover the extra cost of herbicide. The full-post treatment (#1) again proved to be among the most costly in terms of total labor and herbicide.

To assess the impact of more expensive labor, the wage rate was doubled from the standard rate of $6/hr to $12/hr. Because labor was a more prominent component of overall costs at sites with higher weed populations, (Powell and Worland), doubling the wage rate had a more profound effect in generating higher overall costs at these locations relative to sites with lower weed pressure (Torrington and Wheatland). However, the rankings of treatments with respect to total cost changed very little with the elevated wage rate.

**Cost Effectiveness of Preplant and Post Treatments**

The cost effectiveness of applying no-preplant versus one-half preplant versus full preplant herbicide; and the cost effectiveness of selected postemergence programs was analyzed by averaging data from nine of the 12 treatments.

**Preplant**

The cost results of averaging postemergence treatments with identical preplant applications (i.e. #2, #3 and #4 for no-preplant; #6, #7, #8 for one-half rate; and #10, #11 and #12 for full-rate) are shown in the top half of Table 7. While total herbicide and labor costs were similar across preplant options, the composition of costs changed markedly at all locations from less labor to more herbicide moving from no-preplant to one-half to full-preplant.

The effectiveness of preplant treatments was sensitive to increasing the wage rate from $6/hr to $12/hr. Preplant treatments (either one-half rate or full-rate) became notably more cost effective than treatments without preplant. This was true at all locations with cost

**Table 6.** Herbicide and labor costs associated with herbicide treatments by field site.

| | Northwest Wyoming | | | | | | Southeast Wyoming | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | Worland | | | Torrington | | | Wheatland | | |
| Herbicide Treatments | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total |
| | $/ha | | | $/ha | | | $/ha | | | $/ha | | |
| 1. No-preplant + full-post | 86 | 136 | 222 | 74 | 333 | 407 | 82 | 101 | 183 | 84 | 89 | 173 |
| 2. No-preplant + early-post | 62 | 217 | 279 | 52 | 240 | 292 | 40 | 84 | 124 | 42 | 84 | 126 |
| 3. No-preplant + double-post | 109 | 111 | 220 | 91 | 54 | 145 | 67 | 47 | 114 | 69 | 69 | 138 |
| 4. No-preplant + triple-post | 131 | 74 | 205 | 101 | 59 | 160 | 77 | 42 | 119 | 79 | 62 | 141 |
| 5. ½-preplant + no-post | 22 | 220 | 242 | 44 | 393 | 437 | 22 | 59 | 81 | 35 | 91 | 126 |
| 6. ½-preplant + early-post | 84 | 156 | 240 | 94 | 124 | 218 | 59 | 44 | 103 | 77 | 57 | 134 |

**Table 6.** *(Continued)* Herbicide and labor costs associated with herbicide treatments by field site.

| | Northwest Wyoming | | | | | | Southeast Wyoming | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | Worland | | | Torrington | | | Wheatland | | |
| Herbicide Treatments | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total |
| | $/ha | | | $/ha | | | $/ha | | | $/ha | | |
| 7. ½-preplant + double-post | 131 | 86 | 217 | 133 | 44 | 177 | 86 | 32 | 118 | 104 | 47 | 151 |
| 8. ½-preplant + triple-post | 153 | 67 | 220 | 146 | 37 | 183 | 96 | 37 | 133 | 114 | 42 | 156 |
| 9. Full-preplant + no-post | 32 | 212 | 244 | 74 | 351 | 425 | 27 | 52 | 79 | 54 | 49 | 103 |
| 10. Full-preplant + early-post | 94 | 128 | 222 | 126 | 116 | 242 | 67 | 35 | 102 | 96 | 40 | 136 |
| 11. Full-preplant + double-post | 138 | 64 | 202 | 165 | 40 | 205 | 94 | 35 | 129 | 124 | 35 | 159 |
| 12. Full-preplant + triple-post | 163 | 62 | 225 | 175 | 40 | 215 | 104 | 32 | 136 | 133 | 32 | 165 |

**Table 7.** Band applied herbicide and labor costs associated with preplant treatments and post treatments.

| | Northwest Wyoming | | | | | | Southeast Wyoming | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | Worland | | | Torrington | | | Wheatland | | |
| Herbicide Treatments | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total |
| | | $/ha | | | $/ha | | | $/ha | | | $/ha | |
| Preplant | | | | | | | | | | | | |
| None | 101 | 133 | 234 | 82 | 119 | 201 | 62 | 57 | 119 | 64 | 72 | 136 |
| ½-rate | 124 | 104 | 228 | 124 | 69 | 193 | 82 | 37 | 119 | 96 | 49 | 145 |
| Full-rate | 131 | 84 | 215 | 156 | 64 | 220 | 89 | 32 | 121 | 119 | 35 | 154 |
| Post | | | | | | | | | | | | |
| None | 27 | 217 | 244 | 59 | 371 | 430 | 25 | 54 | 79 | 44 | 69 | 113 |
| Early | 89 | 141 | 230 | 111 | 118 | 229 | 64 | 40 | 104 | 86 | 47 | 133 |
| Double | 133 | 77 | 210 | 151 | 42 | 193 | 91 | 32 | 123 | 114 | 40 | 154 |
| Triple | 158 | 64 | 222 | 161 | 40 | 201 | 99 | 35 | 134 | 124 | 37 | 161 |

benefits from using no-preplant to some preplant ranging from $20 to $69/ha ($8 to $28/A). However, very little cost saving was realized from applying preplant at a full versus one-half designated rate.

**Post**

The results of averaging preplant programs with identical postemergence treatments (i.e. #5 and #9 for no-post; #6 and #10 for early-post; #7 and #11 for double-post; and #8 and #12 for triple-post) are shown on the bottom of Table 7. Double-post ($210/ha) proved to be slightly more economical than triple-post at Powell ($222/ha), since the benefit of saved labor from three applications was inadequate to cover the added cost of herbicide. No-post (preplant only) treatments, although inexpensive with respect to herbicide at $27/ha ($11/A), proved to be most costly overall at $244/ha ($99/A) as a result of high weed populations and required labor, costing $217/ha ($88/A). At Worland, double post and triple-post applications were also more cost effective at $193 and $201/ha ($78 and $81/A) than one early-post treatment at $229/ha ($93/A). All three of these options were substantially better than no-post at $430/ha ($174/A). In spite of having the lowest herbicide cost at $59/ha ($24/A), an extremely high labor charge of $371/ha ($150/A) was associated with the no-post option.

With lower weed pressure in southeast Wyoming, the effectiveness of post treatments was nearly reverse from those observed in northwest Wyoming. At Torrington, the no-post (or preplant only) option was the most cost effective at $79/ha ($32/A), while double and triple-post combinations were considerably more expensive at $124/ha and $134/ha ($50/A and $54/A), respectively. The cost effectiveness of alternative post options was similar at Wheatland. In summary, because of lower weed populations at both sites, the labor savings associated with extra post treatments (from no-post to early to double to triple-post) did not compensate for the added cost of herbicide and its application.

Doubling the wage rate from $6 to $12/hr, had virtually no effect on the cost ranking of postemergence treatments. However, the cost advantage of the more economical double and triple-post programs increased considerably (relative to no-post or early-post programs) at the higher weed density sites (Powell and Worland), given a higher wage rate.

**Evaluation by Number of Spray Operations**

The economic impact of extra operations was examined by classifying individual treatments into programs that required one, two, three, or four spray operations. Herbicide and labor costs for these respective treatments were averaged and are summarized in Table 8. Total costs (herbicide plus labor) associated with alternate times over

**Table 8.** Band applied herbicide and labor costs associated with various numbers of operations.

| | Northwest Wyoming | | | | | | Southeast Wyoming | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Powell | | | Worland | | | Torrington | | | Wheatland | | |
| Number of Operations | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total | Herbicide | Labor | Total |
| | $/ha | | | $/ha | | | $/ha | | | $/ha | | |
| One-time over | 49 | 198 | 247 | 62 | 329 | 391 | 42 | 74 | 116 | 54 | 79 | 133 |
| Two-times over | 94 | 133 | 227 | 104 | 99 | 203 | 64 | 42 | 106 | 82 | 54 | 136 |
| Three-times over | 133 | 74 | 207 | 133 | 47 | 180 | 86 | 35 | 121 | 101 | 49 | 150 |
| Four-times over | 158 | 64 | 222 | 160 | 40 | 200 | 99 | 35 | 134 | 124 | 37 | 161 |

(from one to four times over) were very similar. However, the proportion of herbicide and labor changed markedly with each extra operation. At all locations, higher herbicide costs were incurred with additional spray operations. However, lower labor costs were concurrently realized with extra herbicide and weed control. Total cost was reduced with an extra operation, as long as the added cost of purchasing and applying more herbicide was more than offset by savings in labor for hoeing.

At all locations, labor costs dropped sharply from one to two operations. However, further reductions in labor costs became quite modest moving from two to three or more operations. Three spray operations proved to be least costly at both Powell and Worland. However, because of lower weed densities, two operations were most economical at Torrington and one operation was optimum at Wheatland. Because total cost differences between alternative numbers of spray operations are not very large, the choice of fewer versus extra herbicide operations depends largely on individual preferences for managing weeds with less herbicide and more labor as opposed to more herbicide and less labor.

Doubling the wage rate for labor from $6 to $12/hr magnified the cost difference between categories representing different numbers of spray operations. In northwest Wyoming, three operations were again most economical at Powell costing $284/ha ($115/A) and at Worland $230/ha ($93/A). However, because of higher labor requirements at these sites, the margin of economic advantage from using three applications (versus only one or two) was more pronounced with the elevated wage rate. Specifically, at $6/hr, total cost reductions resulting from increasing the number of operations from one (1x) to three (3x) times over were $40/ha ($16/A) at Powell, and $210/ha ($85/A) at Worland. In contrast, much larger cost reductions of $158/ha ($64/A); and $489/ha ($198/A) were realized at these same locations, moving from one (1x) to three (3x) herbicide applications with the higher $12/hr rate.

Because weed densities and resulting labor requirements were much lower in southeast Wyoming, overall cost differences between alternative numbers of applications did not change as much with the elevated $12 wage rate. However, the higher wage rate did cause one major shift in rankings. A single operation became the most costly with the $12/hr rate ($190/ha ($77/A) at Torrington; and $212/ha ($86/A) at Wheatland) after being among the most economical at $6/hr.

## DISCUSSION

In general, the ranking of herbicide treatments with respect to cost changed very little when the charge for labor was doubled from $6 to

$12/hr. However, doubling the wage rate shifted the advantage toward using some preplant (versus no preplant) in combination with postemergence; and in some cases promoted the need for an extra post application. However, very little if any cost advantage was realized from applying preplant herbicide at a full versus one-half rate at either $6/hr or $12/hr.

The economic benefit of using extra herbicide in the context of preplant followed by multiple postemergence treatments is highly dependent upon the status of prevailing weed populations, as noted by contrasting results between sites at northwest versus southeast Wyoming. Although preplant followed by postemergence treatments performed well in most cases, the economic benefit of shifting from double to triple-post was frequently negligible, even at the elevated $12/hr wage rate for labor. This appears to be consistent with the economic principle of diminishing returns, which reflects reduced marginal benefits (savings of labor in this case) continually occurring from expanded usage of a particular input (herbicide in this case). For those preferring lower input options, the results are encouraging, in that applying more herbicide from current positions of moderate to high usage is not always economical, and if so, by only a narrow margin in most cases.

Finally, the distribution and timing of herbicide applications is important. Compared to multiple-post emergence systems, applying similar amounts of herbicide with a one-time full-post treatment was consistently ineffective with respect to weed control. This option resulted in extremely high labor costs, thus placing it among the most costly of all treatments at all locations.

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