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## Peas Are Drought Tolerant!

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### Introduction

Alternative crops are needed to diversify the spring wheat systems in the semi-arid prairie. Crops must be well adapted to this water-limited climate to be considered as potentially profitable alternative crop options. Pea has been reported to yield well in water-limited conditions around the world (Armstrong et al. 1994, Martin et al. 1994, Ney et al. 1994, Lecoeur and Sinclair 1996). In the prairies, research results from Swift Current and Scott, plus numerous testimonials from producers, indicate that dry pea is a good option for the semiarid prairie. This paper visits new research evidence from a multi-site, multidisciplinary research project investigating crop water relations to explain the apparent adaptability of pea to this semiarid climate.

### Drought Definition

In this paper drought tolerance is defined practically as the ability of a crop to make yield efficiently from limited water by the following relationship

$$\text{yield} = \text{water transpired} \times \text{water use efficiency} \times \text{harvest index}$$

where water use efficiency is defined as the amount of above-ground dry matter produced per unit of water and harvest index is the ratio of grain to above-ground dry matter (Passioura 1994). Ludlow and Muchow (1990) list 16 genetic traits related to crop drought tolerance:

1. Matching phenology to water supply
2. Photoperiod sensitivity
3. Developmental plasticity
4. Mobilization of preanthesis dry matter
5. Rooting depth & density
6. Low root hydraulic conductance
7. Early vigour (canopy)
8. Leaf area maintenance ('stay-green')
9. Osmotic adjustment
10. Low lethal water status
11. Reduced stomatal conductance
12. Leaf movements
13. Leaf reflectance
14. Heat tolerance of seedlings
15. Low epidermal conductance
16. Transpiration efficiency

Discussion of the net effect of several traits is necessary to assess the drought tolerance of any crop relative to another. All aspects of the yield relationship are compared between spring wheat and pea by discussing drought tolerance traits in related experiments.

### Water Transpired

A crop that is able to increase the amount of water transpired relative to another crop grown in the same water-limiting yield conditions, accumulates greater plant biomass. Increased water transpiration can result from increased soil water extraction by a deeper and/or denser root system (Trait 5.) or by osmotic adjustment within its leaves (Trait 9.) to exert stronger tensions. In water conditions ranging from full irrigation to imposed drought, pea has clearly shown a shallower rooting habit than spring wheat (Fig. 1), resulting in significantly less water extraction in the 60-120 cm soil layer (Table 1).

Table 1. Yield, water use, and water use efficiency (WUE) by wheat and pea grown on fallow at Swift Current and Stewart Valley, 1995-97.

|               | Seed Yield | Soil Water Use X Depth  |           |          | Seed WUE |
|---------------|------------|-------------------------|-----------|----------|----------|
|               |            | 60-90 cm                | 90-120 cm | 0-120 cm |          |
|               | kg/ha      | ----- mm of water ----- |           |          | kg/ha/mm |
| Katepwa wheat | 3100a      | 36a                     | 20a       | 124a     | 9.5a     |
| Grande pea    | 2630b      | 15b                     | 8b        | 89b      | 9.2a     |

Values within a column followed by the same letter are not different ( $P < 0.05$ ).

Further, pea is less able to adjust osmotically to maintain an adequately hydrated plant structure (Fig. 2), however, recent evidence suggests that pea operates at a lower 'setpoint' for relative water content compared to wheat (Fig. 3), which may mean osmotic adjustment is less important for pea than for wheat. Regardless, it is clear that wheat has the ability to transpire greater amounts of water than pea, which affords wheat more of a key limiting resource with which to make yield.

### Water Use Efficiency

The growing season climate in the semiarid prairie is characterized by a steadily increasing water deficit that frequently results in summer drought severe enough to terminate crop growth prematurely. As such, a crop that matches its phenology to this summer drought pattern can be expected to avoid the most severe effects of the drought (Trait 1.) The low humidity and high wind speeds common to the semiarid prairie also result in large evaporative losses from the soil surface. A crop which extracts the soil water in the surface quickly can be expected to minimize losses of this surface layer water (Trait 7.). The earlier onset of reproductive growth in pea, coupled with its ability to be seeded very early into cold soils, provides pea with an opportunity to escape the most severe drought stress (Fig. 4). In a 'normal year, pea seeded April 21 will reach the 50% grain fill stage 17 days ahead of

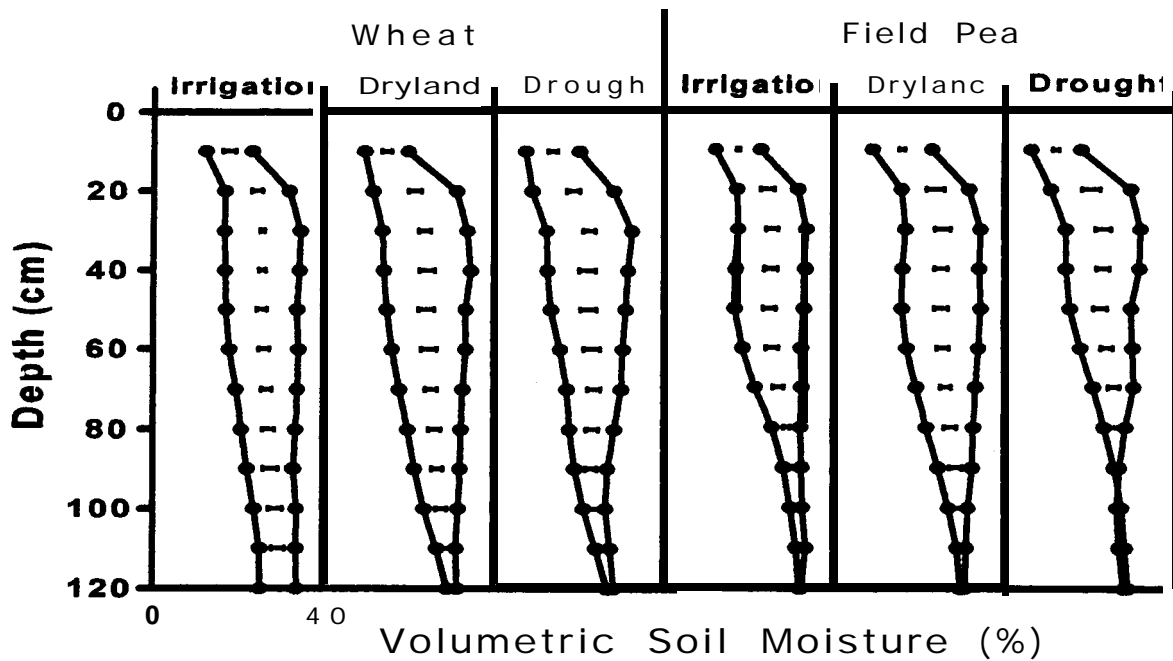


Fig. 1. Rooting patterns of wheat and pea at seeding and harvest, grown in irrigated, dryland, and imposed drought conditions at Swift Current 1997.

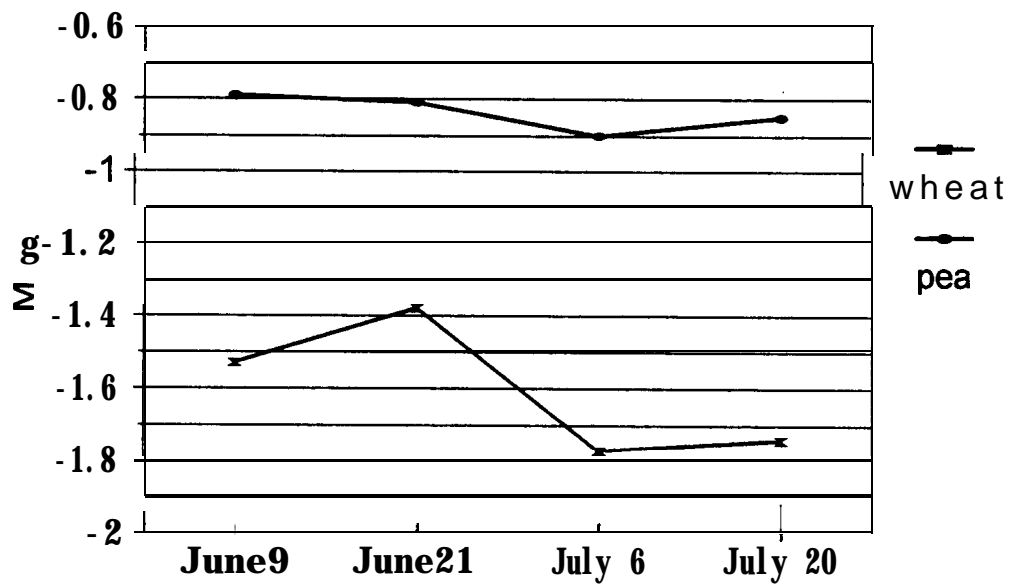


Fig. 2. Osmotic adjustment for Katepwa wheat and Victoria pea grown at Carman, 1989.

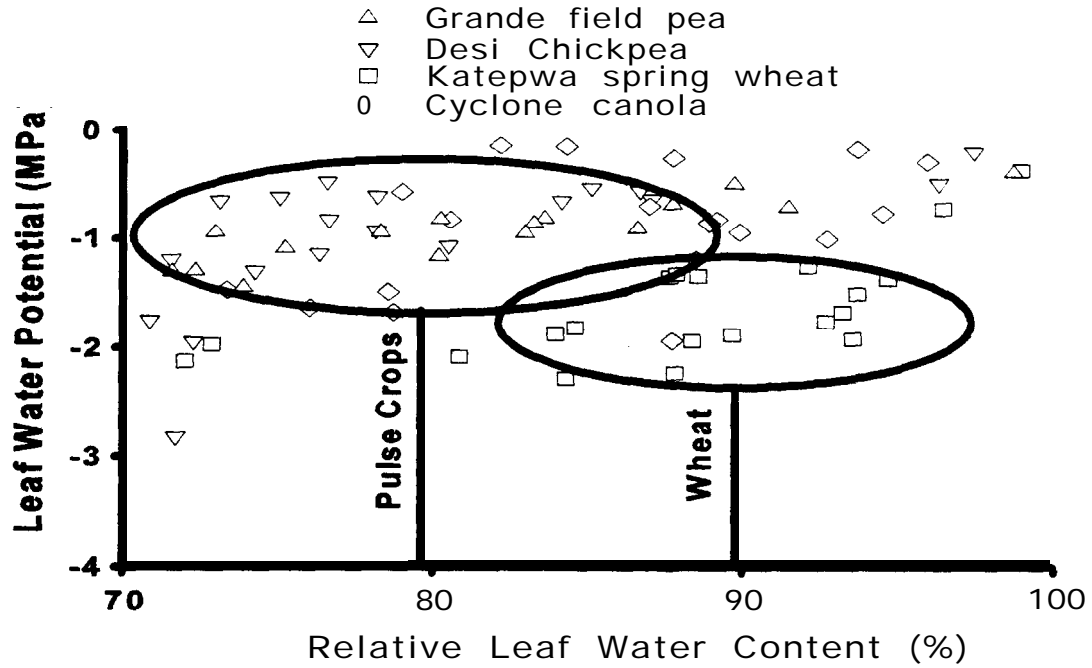


Fig. 3. Relative leaf water content vs. leaf water potential for 4 crops grown at Swift Current in 1997.

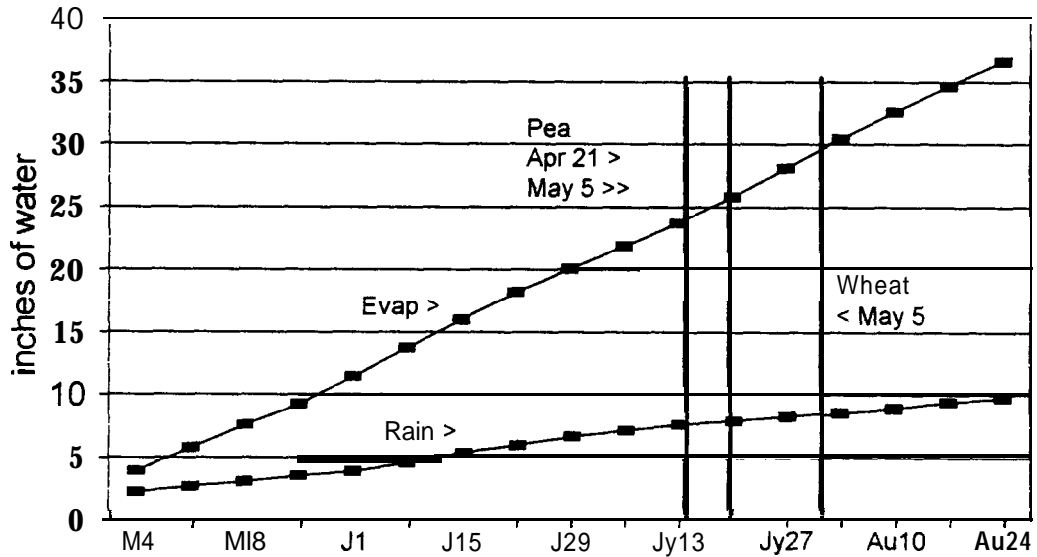


Fig. 4. Water deficit at 50% grain fill stage for pea sown on 21 April and for pea and wheat sown on 5 May, based on normal climatic values at Swift Current, 1960-97.

spring wheat, allowing it to till grain during less stressful climatic conditions. Further, pea has an ability to extract available water from the surface soil layer more quickly than wheat, minimizing losses to evaporation (Fig. 5). The pattern of dry matter accumulation differed markedly between wheat and pea, with wheat accumulating relatively more of its total biomass during the vegetative growth stage in both years (Table 2). The total dry matter accumulation in wheat was much higher, so, despite greater soil water use, the water use efficiency of biomass production was higher than pea.

Table 2. Vegetative and reproductive dry matter accumulation, biomass and seed water use efficiency, and harvest index for wheat and pea averaged for fallow and stubble sites at Swift Current in 1996 and 1997.

| Crop and Year | DM accumulation |              | Water Use Efficiency |      | Harvest Index |
|---------------|-----------------|--------------|----------------------|------|---------------|
|               | Vegetative      | Reproductive | Biomass              | Seed |               |
|               | t/ha            |              | kg/ha/mm             |      |               |
| 1996          |                 |              |                      |      |               |
| Katepwa wheat | 4.6a            | 3.1b         | 22.7a                | 7.7a | 0.34b         |
| Grande pea    | 2.0b            | 4.2a         | 19.0b                | 8.2a | 0.44a         |
| 1997          |                 |              |                      |      |               |
| Katepwa wheat | 2.4a            | 6.5a         | 23.5a                | 8.6a | 0.37b         |
| Grande pea    | 1.2b            | 5.1b         | 19.0b                | 8.7a | 0.46a         |

Values within a column within a year followed by the same letter are not different ( $P < 0.05$ ).

### Harvest Index

Harvest index values are typically larger for pea, compared to spring wheat (Table 2). Why are harvest index values higher for pea than for wheat? Is there a genetic basis for this phenomenon? Genetically programmed differences in plant growth patterns probably explain at least part of the difference in harvest index between these two crops. Pea invests relatively little photosynthate in root growth as shown by the root:shoot ratios measured at Scott (Fig. 6). Are there additional environmental reasons why harvest index values for pea are typically greater than wheat? Passioura (1994) states that a crop which takes a 'conservative' approach to vegetative growth, in the face of terminal drought stress, will normally have a higher harvest index. A crop which accumulates too much dry matter prior to anthesis will be subject to 'haying off' as water resources become increasingly limiting to growth, resulting in a reduced harvest index. The contrasting ratios of dry matter accumulation between vegetative and reproductive growth stages, indicates strikingly different plant growth patterns between wheat and pea. Wheat invests heavily in vegetative growth, growing a large root system for vigorous soil exploration and a dense grass canopy for maximum photosynthesis. We call this an 'optimistic' growth strategy because it is dependent on continued favorable climatic conditions during the reproductive growth phase. Conversely, pea appears to have a more 'pessimistic' outlook, choosing to initiate reproductive growth earlier and devote photosynthate to the seed, resulting in a high WUE

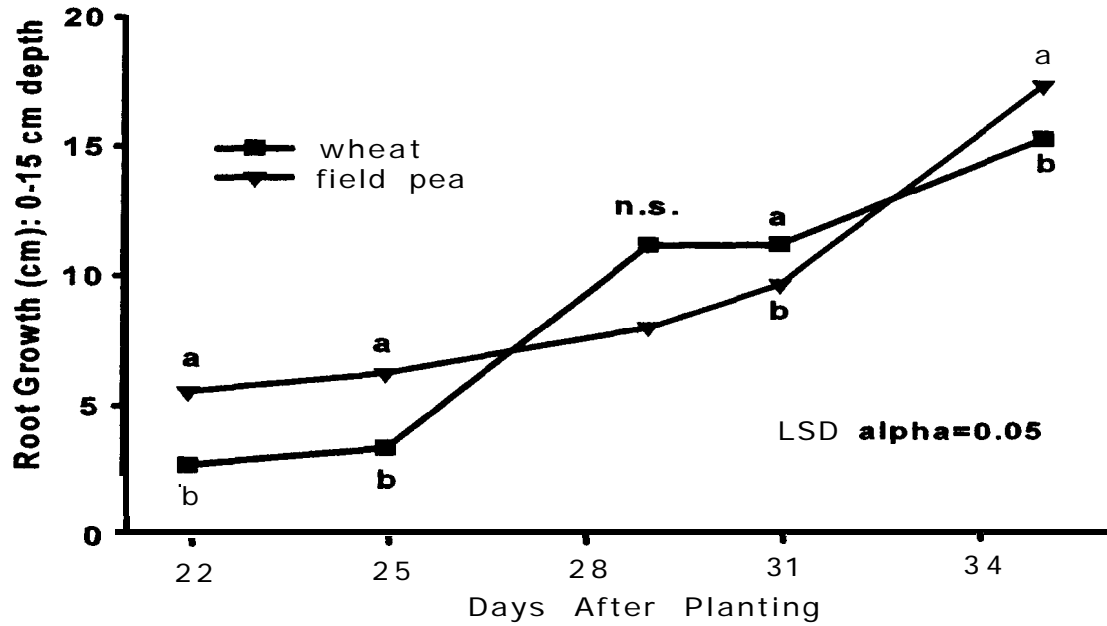


Fig. 5. Lateral root growth of wheat and pea in the 0-15 cm soil layer at Carman, 1997.

## Root:Shoot Biomass

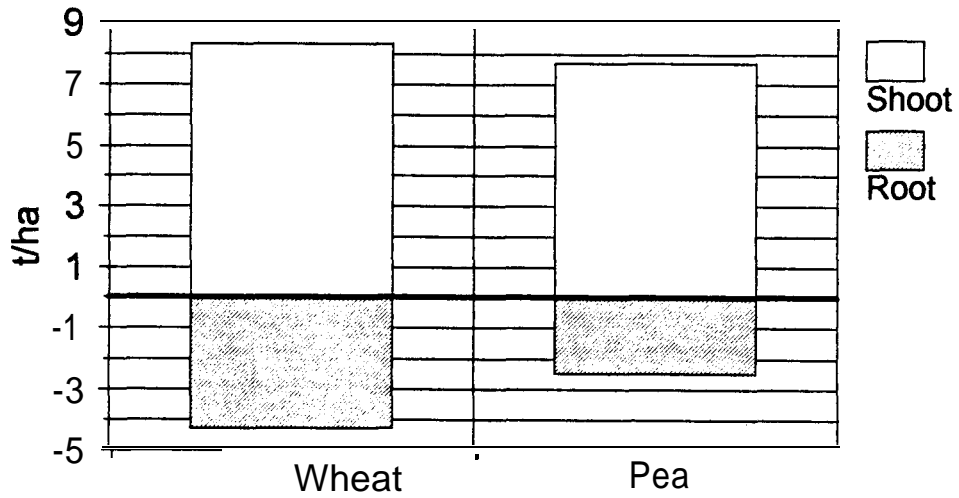


Fig. 6. Average root and shoot biomass values for wheat and pea grown at Scott, 1991, 1993-96.

for seed yield (Fig. 7).

### Crop Yield

Although pea is less effective than wheat at extracting soil water for transpiration, and is also less efficient in the conversion of water to plant biomass, a higher harvest index compensates sufficiently to result in net seed yields that often do not differ greatly (Tables 1 & 3). Harvest index is the key factor that causes the WUE of seed yield (i.e. WUE of biomass X harvest index) to be similar between wheat and pea. We have evidence that WUE increases for pea as water becomes less available, indicating good drought tolerance (Fig. 8).

Table 3. Seed yield for wheat grown on fallow and wheat and pea grown on wheat stubble with conventional tillage. on a clay soil at Stewart Valley, 1996-97.

| Year | Wheat on fallow | Seed Yield       |                |
|------|-----------------|------------------|----------------|
|      |                 | Wheat on stubble | Pea on stubble |
|      |                 | <b>bu/ac</b>     |                |
| 1996 | 44.9a           | 33.9b            | 45.7a          |
| 1997 | 47.8a           | 37.4b            | 32.8b          |

Values within a row followed by the same letter are not different ( $P < 0.05$ ).

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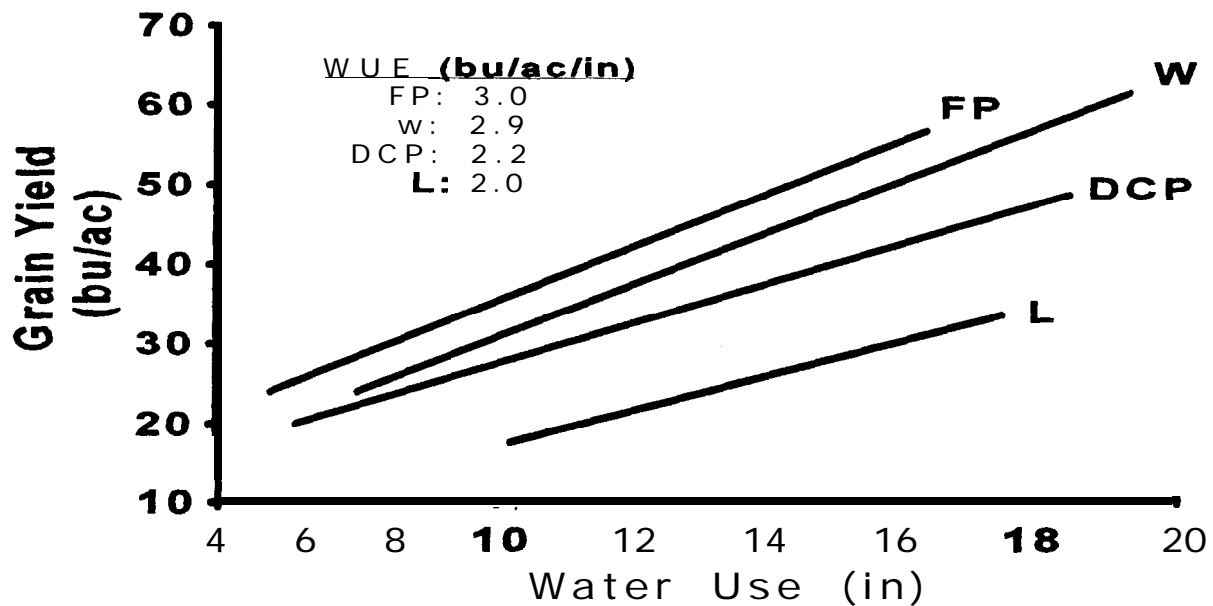


Fig. 7. Water use efficiency for seed yield for field pea (FP), wheat (W), desi chickpea (DCP) and lentil (L) grown under irrigated, rainfed and imposed drought field conditions at Swift Current, 1996-97.

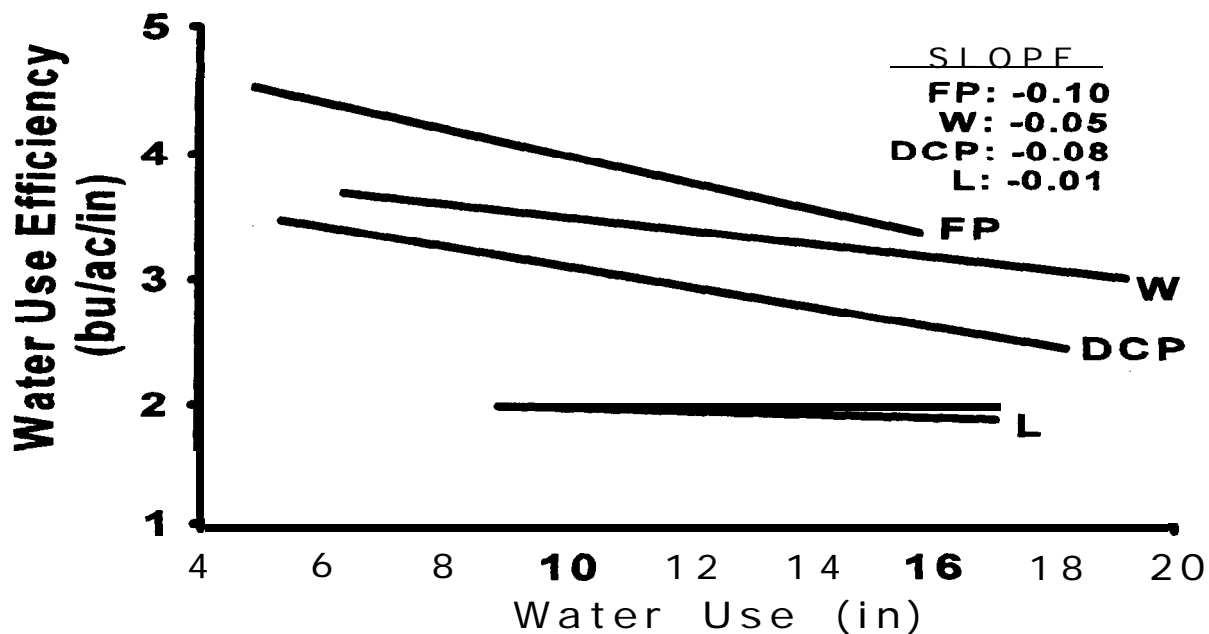


Fig. 8. Water use vs. water use efficiency for seed yield for field pea (FP), wheat (W), desi chickpea (DCP) and lentil (L) grown under irrigated, rainfed and imposed drought field conditions at Swift Current, 1996-97.



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