Summary  One of the major weed species of the dryland cropping region of the Pacific Northwest (PNW) in the USA is Russian thistle (*Salsola* spp.). Sixty percent of the wheat-producing area of the PNW is an arid to semi-arid region characterised by severe wind erosion because of intensive tillage during the dust-mulch fallow period between winter wheat crops. Attempts to reduce the number of erosive fallow hectares by growing no-till spring crops have been impeded by Russian thistle. This weed thrives in this environment because it is capable of season-long germination and seedling establishment, even with very short periods of moisture after light rains (2.5 mm). Russian thistle is a shallow germinating weed and therefore flourishes in trashy, no-till environments. It reduces farm income by reducing crop yield and quality and increasing production costs. Russian thistle is very competitive because of its high water use efficiency and its rapid and extensive root growth in early spring. After crop harvest, Russian thistle produces an abundance of biomass and seed. It also extracts soil moisture to a point that soil recharge by winter and spring precipitation may not be sufficient to produce a crop the following year.

Russian thistle management strategies must focus on preventing seed production throughout the crop rotation cycle. This includes in the crop, after crop harvest, and during the fallow period. If spring crops are planted, growers must use management practices that optimise crop competitiveness with Russian thistle. Furthermore, neighbours must also control their Russian thistle so that reinfestation does not occur by seed dispersal from the wind-driven tumbling weeds.

Keywords  Competition, drought-tolerant, herbicide resistance, post-harvest growth, root development, seed production.

INTRODUCTION  
Russian thistle (*Salsola tragus*) is a summer annual broadleaf weed infesting arid and semi-arid agricultural and non-crop lands in more than 40 countries world-wide (Holm *et al*. 1997). The weed is known by more than 20 common names, with the most recognised being Russian thistle, Russian tumbleweed and prickly saltwort. The taxonomy of Russian thistle is highly varied with numerous species identified, or possibly misidentified. For example, since the 1980s Russian thistle has been referred to as *S. kali* (L.), *S. iberica* (Sennen and Pau), and more recently, as *S. tragus* in the PNW (F. Ryan and F. Hrusa personal communication).

The history of Russian thistle in North America is rich and colourful. The ‘tumbleweed’ has been entrenched into the folklore of the western frontier and has actually been called ‘the weed that won the west’ (Young and Evans 1985). Rarely has an introduced plant species spread as rapidly as Russian thistle. The weed was brought into the central United States (South Dakota) in 1873 from Russia in flax seed. By the turn of the century, it had reached the Pacific Ocean.

Russian thistle infests an estimated 41 million ha in the western United States (Young 1991). In the PNW, Russian thistle infests about 1.8 million ha of cropland and costs growers more than $50 million annually in lost crop yield, reduced quality, and the cost of control. It is the dominant broadleaf weed species in the intermediate and low rainfall zones where winter wheat (*Triticum aestivum* L.)-fallow is the main crop rotation (Young and Gealy 1986). This weed is the main pest preventing the adoption or adaptation of alternative broadleaf crops such as spring dry pea (*Pisium sativum* L.), canola and mustard (*Brassica* spp.). The focus of this paper is on the biology and management of Russian thistle in the semiarid crop production region of the PNW, USA.

BIOLOGY

Seed characteristics  
Russian thistle is an extremely prolific seed producer. Pammel (1894) reported that an individual plant grown in the central United States produced from 20 to 30,000 seeds whereas in the PNW, an individual plant can average 152,000 seeds (Young 1986). Two agronomists with the United States Department of Agriculture have conducted the most comprehensive studies on the biology of Russian thistle seeds (Young and Evans 1972, Evans and Young 1972). The studies were conducted on non-cropland in arid and semiarid regions of the Great Basin area of western North America. Russian thistle seed biology studies (Young 1986, Schillenger and Young 2000) conducted in cropland areas of the inland PNW have generally agreed with Young and Evans’ research findings.
Russian thistle seeds consist of a fully differentiated, coiled ‘seedling’ in the form of a spiral helix. The seed is a spiral embryo that does not contain endosperm. In general, Russian thistle seed requires very little water to germinate, can withstand several wetting and drying periods, and begins to emerge in March (Young et al. 1995). Seeds have a short longevity in the soil with soil compaction and seed burial affecting germination and establishment. When mature, the plant may break-off at the soil surface, tumble in the wind, and dislodge seed from the plant. Seed dispersal can be up to 4 km depending on wind speed and direction, crop residue, and other obstacles.

**Plant characteristics**  
In the PNW, once established, Russian thistle begins to flower in mid-June and continues to flower until early November or until a killing frost occurs. Russian thistle is most problematic in spring cereals which are not as competitive as winter wheat. Russian thistle can severely reduce spring wheat yield, especially when moisture is limiting. Yield reduction can be as high as 2.3% for each week of competition (Young 1988). Percent yield reduction depends on rainfall and early spring wheat establishment (Table 1). Yield reduction of spring wheat was the least in 1984 (11%) even though Russian thistle density was 50 to 60% higher compared to 1983 and 1985 respectively. Spring wheat gained the competitive edge because it emerged one week earlier in 1984 and two weeks earlier than Russian thistle.

In general, aggressive weed competitors establish root systems early and contain deep penetrating main roots and fibrous subsurface roots. A study was conducted in 1996 and 1997 to investigate the root development of Russian thistle in spring wheat using a mesorhizotron and scanning system (Pan et al. 2001). Root development was rapid and extensive in early spring, reaching a soil depth of 120 cm within the first seven to 10 weeks after germination with high root densities appearing in the 90 to 120 cm-depth (Pan et al. 2001). Over a 14 day period, the tap root extended to over 60 cm while shoot height increased only 5 cm. Soon after the rapid early season growth, roots began to shrink and die back until Russian thistle shoots were cut at crop harvest (Pan et al. 2001). Roots then regenerated in old root channels within seven days after harvest.

The early root development of Russian thistle compared to shoot development helps explain the depletion of soil water (Schillenger and Young 2000) and subsequent spring wheat yield loss during the year (Young 1988). Russian thistle can remove almost 70 L plant$^{-1}$ of soil moisture when competing with a spring wheat crop. However, considerable damage is rendered by Russian thistle after harvest. Over 90% of the plants’ annual growth and seed set occur after wheat harvest (Young 1986). If allowed to grow unmo- lested between crop harvest and the first killing frost in the fall, each Russian thistle plant can extract 100 L water, produce more than 1000 g of biomass, and produce up to 67,000 seeds (Schillenger and Young 2000). Russian thistle depleted soil water in a 0.6 m diameter circle to a depth of 1.8 m. Soil moisture was extracted from a 3 m diameter from the base of the plant. The implication of this soil moisture depletion is that during an average precipitation year, the soil is recharged only to 0.75 m deep, which is insufficient for annual spring cropping systems.

**MANAGEMENT**  
Russian thistle is a problem in the growing crop, post-harvest, and during the summer-fallow season (Young et al. 1995). Flushes of Russian thistle can emerge numerous times during the year following very light rains. In the mid-1980s the use of sulfonylurea herbicides provided effective residual control of Russian thistle. However, widespread Russian thistle resistance to this family of herbicides occurred rapidly. Current research and grower experiences have indicated that effective weed control, soil conservation practices, and farm profitability are compatible. One must capitalise on windows of opportunity to control Russian thistle in the growing crop, pre-harvest, post-harvest, during summer fallow, and in field borders and roadways (Young et al. 1995). Preliminary research using a reduced pesticide sprayer for post-harvest Russian thistle control shows promise. Herbicide use and subsequent cost has been reduced up to 45% while effectively controlling the weed. A few soil conservation districts in the PNW have purchased these sprayers and plan on leasing them to interested growers. Above all, one must rotate families of herbicides and refrain from using the same family of herbicides on the same crop grown in the same field to control the same weed year after year.

### Table 1. Spring wheat yield losses from Russian thistle in low-rainfall zone of eastern Washington, USA.

<table>
<thead>
<tr>
<th>Year</th>
<th>Weed density (No. m$^{-2}$)</th>
<th>Yield loss (%)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>54</td>
<td>31</td>
<td>100</td>
</tr>
<tr>
<td>1984</td>
<td>107</td>
<td>11</td>
<td>140</td>
</tr>
<tr>
<td>1985</td>
<td>43</td>
<td>55</td>
<td>45</td>
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REFERENCES