Development of 'Grasslands Puna' Chicory (*Cichorium intybus* L.) Seed and the Determination of Time of Harvest for Maximum Seed Yields[1]

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ABSTRACT

Seed development studies showed that seed maturity and harvest maturity in chicory (*Cichorium intybus* L.) cv. Grasslands Puna occurred at the same time, 20 days after pollination. Maximum seed germination occurred three days before seed and harvest maturity. Seed color was a good indicator of seed maturity in both years. The optimum time to harvest was from 20 to 30 days after peak flowering, when the seeds were deep brown and seed moisture content was less than 40%.

Additional index words: **seed development, harvesting time, germination.**

INTRODUCTION

Chicory (*Cichorium intybus* L.) is a perennial herb of the family Compositae. It is most commonly used as a leaf vegetable ('witloof') (Clapham et al., 1962) and a supplement for coffee (Prem Singh Arya and Saini, 1984). In parts of England it has been included in seed mixtures as a forage plant, where on shallow chalky soils its deep tap-root breaks up the subsoil (Clapham et al., 1962), produces high yields of palatable feed for cattle and sheep, has high mineral levels and good drought resistance (Rumball, 1986). In New Zealand chicory has become naturalized in many parts and is often seen along roadsides, particularly during the summer (Cheeseman, 1906; Taylor, 1981).

Cv. Grasslands Puna chicory was bred as a pasture forage herb by Grasslands Division, DSIR, Palmerston North, New Zealand and approved for national listing, commercial release and certification in 1985 (Rumball, 1986). Puna chicory has very little winter growth, but it responds very quickly to warm spring temperatures (Lancashire and Brock, 1983). It is most useful as a perennial summer forage providing large quantities of feed from spring through to autumn, in dry warm regions, on medium to high fertility well-drained soils. Yields of over 200 kg DM ha^{-1} day^{-1} from October to February have been recorded (Hare and Rolston, unpublished).

Seed of Puna chicory has been produced only since 1984 as nucleus seed (Rolston and Gomez, 1986) at the Grasslands Aorangi farm, Manawatu, New Zealand. The main difficulty of seed production is that flowering proceeds over a period of two to three months (December to February) resulting in seed of various maturities at harvest. The seed at maturity sheds easily, more so if strong winds blow and heavy rain falls. Birds feed readily on mature seed.

Even though flowering is prolonged, Puna chicory does produce a definite peak flowering period over one week (Hare and Rolston, unpublished). The pale blue ray flowers of Puna chicory open in the early morning and are usually closed by mid-afternoon following cross-pollination by honey bees (Clapham et al., 1962; McGregor, 1976). The seeds are in the form of achenes with a pappus of small scales at one end. Each inflorescence contains 15 to 25 seeds and each seed is 2.5-3 mm in length with a one thousand seed weight (TSW) of 1.3 to 1.7 grams.

In order to determine the optimum harvesting time in species with long flowering patterns, seed development and flowering have been studied, particularly in grasses and herbage legumes (Hill and Watkin, 1975; Hare and Lucas, 1984). Studies on Compositae are limited mainly to leaf lettuce (*Lactuca sativa* L.) (Soffer and Smith, 1974; Globerson, 1981; Sukprakarn, 1985). Seed development is associated with an overall loss of moisture (Adams and Rinne, 1980) and is concerned with the various stages from pollination to when the seed is first fully mature and then when it is ready to harvest (Mullett, 1981). Seed maturity is the point at which maximum dry weight is first reached (Hyde, 1950). Seeds are ready to harvest when they have dried to a suitable moisture content to process through seed machinery (Delouche, 1980). Compositae seed harvested well before seed maturity have very high moisture contents (> 70%) and upon drying shrivel, have low TSW, low germination and poor seedling vigor (Soffer and Smith, 1974; Globerson, 1981). If harvesting is delayed until well after seed maturity, large shattering losses will occur (Sukprakarn, 1985).

This investigation studied the development of seeds from pollination and the effect of harvesting at set intervals following peak flowering. The aim of this work was to define the optimum time for seed harvesting of Puna chicory.

MATERIALS AND METHODS

The trial was conducted at the Grasslands Division, DSIR Aorangi farm in the Manawatu (40°S) over the 1984/85 and 1985/86 summer seasons on a stand of Puna chicory sown in October 1982. Details of field management are given in Table 1.

Seed development: Following pollination at peak flowering 300 flowers were tagged with colored wire in each of four plots. Every three days from eight days after pollination, 20 inflorescences per plot were taken and the following observations and measurements made:

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Table 1. Field management details

Sowing date	October 15, 1982.
Sowing rate	4 kg ha^{-1}
Row spacing	60 cm row width.
Herbicides	1982 Trifluralin 0.4 kg a.i. ha^{-1} pre-emergence October 20th. 1983 Propryzamide 0.5 kg a.i. ha^{-1} July. 1984 Paraquat 0.4 kg a.i. ha^{-1} and atrzine 0.5 kg a.i. ha^{-1} on May. 1985 Atrazine 0.5 kg a.i. ha^{-1} May and atrazine 0.25 kg a.i. ha^{-1} August.
Insecticides	Dichlorvos 0.61 a.i. ha^{-1} in December 1983 and 1985 to control aphids and tomato fruit caterpillar.
Fertilizer	60 kg N ha^{-1}. Applied in October.
Inter-row cultivation	Rotary hoed between rows in May of each year.
Post-harvest management	All plots were cut after harvest and combine harvested for residual seed. Threshings were windrowed and burned. All plots were grazed in May to ground level. No winter grazing.
Plot size	4.8 m x 5 m.

1) Seed fresh weight, dry weight and moisture percentage on four replicates of 50 seeds per plot. Seeds were dried at 103°C for 17 hours (ISTA, 1985).

2) Germination percentage. Four replicates of 25 seeds per plot were germinated on top of blotting paper, with 0.2% KNO, at 20°C in darkness for 16 hours and 30°C in light. Counts were taken at 5 and 14 days (ISTA, 1985).

Sequential harvesting: In the 1984/85 season only, flowering counts of open flowers at pollination were taken weekly from one meter rows in three plots closed on August 1. Sequential seed harvests were taken every three days from January 16 to January 31, 1985.

RESULTS

Meteorological Data

Over both seasons the average maximum temperatures for the period of seed development was 23°C and the minimum temperature 12.8°C (Figure 1). Rainfall for this period in the first season was 153 mm and the second season 35 mm.

Seed development

There were no major differences in seed development between seasons so the results presented are a mean of both seasons.

Fresh weight: Up to 14 days after pollination there was no significant difference in seed fresh weight (Figure 2). From 14-17 days onwards fresh weight increased significantly

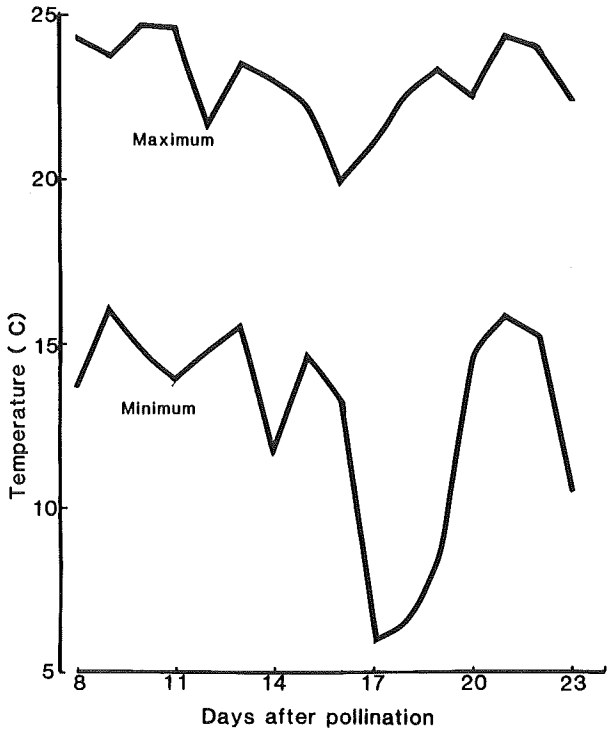

Figure 1. Maximum and minimum temperatures from 8 to 23 days after pollination.

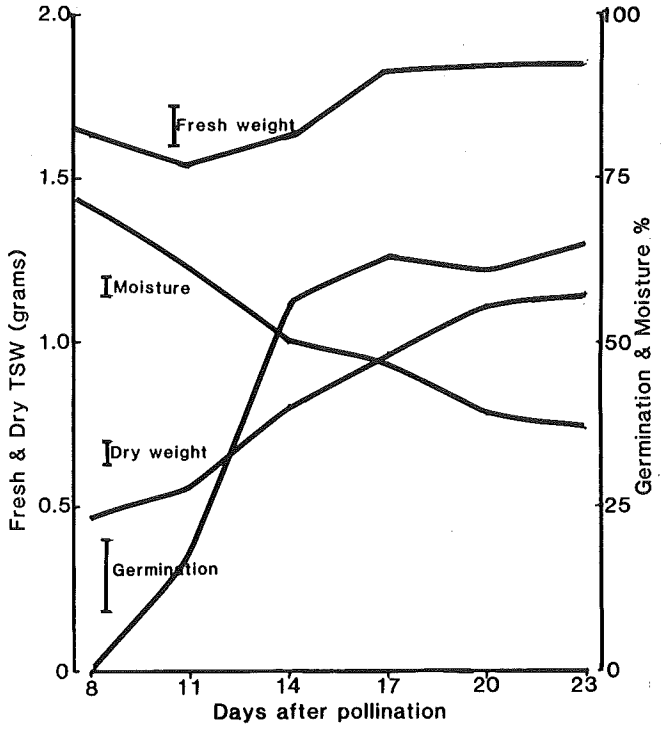

Figure 2. Puna chicory fresh weight, dry weight, moisture percentage and germination percentage from pollination. (Bars = LSD 0.05).

($P<0.05$). Maximum TSW fresh weight of 1.85 g was reached by 17 days; thereafter, there was no significant increase in fresh weight.

Dry weight: There were highly significant ($P<0.001$) increases in the dry weight of Puna chicory seeds up to 20 days after pollination when maximum dry weight (seed maturity) was reached (Figure 2). From 20 to 23 days there was no signficant dry weight increase.

Seed moisture: Seed moisture decreased rapidly ($P<0.001$) from 8 to 14 days, slowed ($P<0.05$) and then decreased rapidly ($P<0.001$) from 17 to 20 days (Figure 2). After 20 days there was only a 1.5% drop in seed moisture. Seed moisture at seed maturity was 39%.

Seed germination: Maximum seed germination of 65% was reached on day 23. There were no significant differences in germination between 14 days (56%) and 23 days (65%) after pollination (Figure 2).

Seed color: Seed were first white with a light green pappus up to 8 days after pollination. Thereafter, seeds began to turn brown and by 14 days were light brown with an off-white pappus. By 23 days seeds were deep brown, some almost black, with a light brown pappus.

Flowering

Peak flowering was on December 31 (Figure 3). Flowering gradually declined in intensity ($P<0.05$) over the following week and then declined significantly ($P<0.001$).

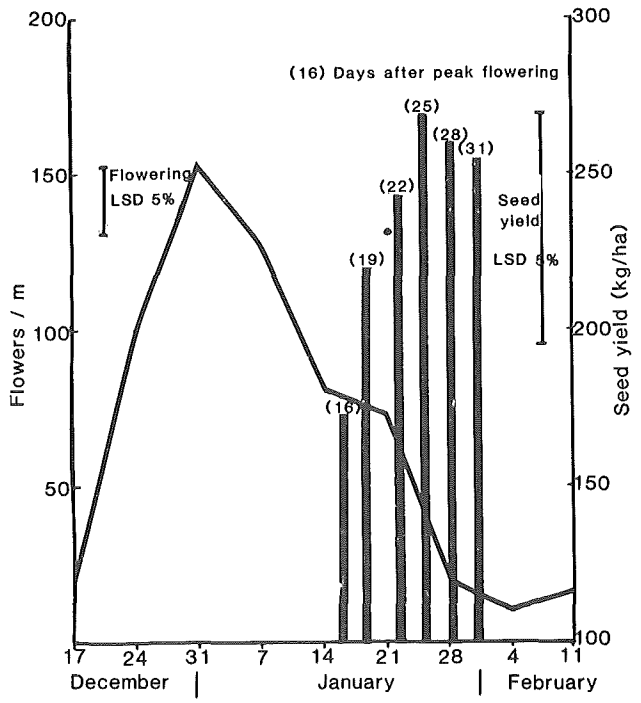

Figure 3. Flowering pattern of Puna chicory and seed yields from 16 to 31 days after peak flowering.

Sequential harvesting

The highest seed yield of 268 kg ha^{-1} was harvested 25 days after peak flowering (December 31). This seed yield was 55% higher than the yield harvested 16 days after peak flowering which was four days before seed maturity. There were no significant differences from the second to the sixth harvests, due to the large variations in seed yields between plots. The sampling area of one meter row was probably too small for such a variable plant as Puna chicory.

DISCUSSION

Seed maturity of Puna chicory seed was reached 20 days after pollination when the seed moisture content was 39%. Sukprakarn (1985) found that in leaf lettuce seed maturity was reached 11 to 13 days after pollination, when seed moisture was between 35 and 40%. Lower seed moistures of 24% were obtained at seed maturity, 14-17 days after pollination in leaf lettuce cultivars in Israel (Globerson, 1981). In both these studies seed developed under higher average temperatures than the temperatures under which Puna chicory seed developed. Globerson (1981) also found that lettuce seed developed at different rates from year to year due to differences in weather. This also occurred in Maku lotus seed development (Hare and Lucas, 1984). Over two seasons Puna chicory seed developed at the same rate even though during seed development in the second season the weather was drier than the first, the daily temperatures were approximately the same. Temperature influences seed development to a greater extent than rainfall (Mullett, 1981).

Harvest maturity (Delouche, 1980) in Puna chicory seed occurred at the same time as seed maturity. In other crops, peanuts, cowpeas, beans (Delouche, 1980) and herbage legumes (Hare and Lucas, 1984), harvest maturity will occur from 7 days to 14 days after seed maturity.

Maximum seed germination of Puna chicory was reached three days before seed maturity, a time similar to that in many cultivars of lettuce (Globerson, 1981; Sukprakarn, 1985). Harvesting at or just after seed maturity results in seed of high 1000 seed weight and high germination.

Sukprakarn (1985) found that two to five days after seed maturity shedding increased rapidly. Puna chicory seed also sheds readily, but in these studies only a very little shedding had occurred three days after seed maturity. From observations, shedding does increase from six days after seed maturity, even though there were no significant differences in seed yield by sequential harvesting from 5 to 11 days after seed maturity. Low seed yields (170 kg ha^{-1}) did occur when seed was harvested 16 days after peak flowering as it was four days before seed and harvest maturity and so the immature light seed separated out during seed cleaning.

Sukprakarn (1985) found that seed color was not a reliable indication of harvest maturity in leaf lettuce. Over both seasons Puna chicory seed changed from light brown to a deep brown at harvest maturity and proved a good indicator of the optimum time to harvest.

In these experimental studies maximum TSW was only 1.15 grams with a germination of 65%, considerably lower than the results from combine harvested and machine cleaned nucleus seed from the same field (TSW, 1.55-1.70 g; germination, 88-92%).

These seeds used in each stage of the seed development studies were from 20 inflorescence per plot, from many different plants and different positions on the plant. The seeds

were all mixed together and large or small seeds were not separated. Even though all these inflorescences were tagged at an identical stage (pollination - blue open ray flowers), inflorescences further down the plant canopy were probably shaded, were subject to lower temperatures than those close to the top of the canopy and, therefore, developed at a slower rate. If these seeds had been cleaned then the light seed would have separated off, leaving heavier seed of higher germination. In lettuce the larger and heavier the seed, the greater the germination percentage (Scaife and Jones, 1970; Smith et al., 1973a,b). This is further illustrated when lighter Puna chicory seed classed as seconds from the cleaning machine in the 1984/85 nucleus seed crop had a lower germination, 75% cf. 88%, and lower TSW, 1.42 cf. 1.70 g, than the top quality seed line.

When Puna chicory seed is combine harvested, the crop is first cut with a mower and left to dry for as long as two weeks. The large stalks contain enough reserves to allow seed development to continue so that slightly immature seeds at mowing will be mature by the time of seed harvest, thereby increasing TSW. Seed in the seed development studies were harvested and tested the same morning, giving no time for immature seeds in inflorescences to further develop. Further studies are now underway to study if there is a correlation between TSW and germination in Puna chicory seed.

The results in these studies indicate the importance of observing when peak flowering occurs in order to harvest the crop 20-30 days after that time to produce maximum seed yields of Puna chicory seed.

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