HORTSCIENCE 32(4):687–689. 1997.

Zinnia Seed Harvest Time Affects Germination and Plant Growth

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Additional index words. seedling growth, seed production, *Zinnia violacea*

***Abstract.* Seeds of 'Kumamotonokagayaki' (Kk), 'Goldenball' (Gb), and 'Purple Gem' (PG) (*Zinnia violacea* Cav.) were harvested at various stages of maturity and subsequent seed and plant performance were evaluated. The largest increase in ovule or embryo length and width occurred from 0 to 10 days after pollination (DAP). The seed weight was unchanged after 23, 25, and 30 DAP for Kk, Gb, and PG, respectively. The pericarp color was completely green from seeds harvested 20 DAP, while the seeds harvested from 30 to 35 DAP contained a mixture of green and brown seeds. Pericarp color change from green to brown was not a reliable index to harvest seeds. The percentage germination increased from seeds harvested from 10 to 19 DAP for all cultivars. From 20 to 40 DAP, germination was unaffected and >90%, while the rate of germination as measured by days to visible germination decreased slightly. Seeds harvested 20 to 40 DAP produced plants with similar growth and quality characteristics. Considering a 20- to 30-day difference between the first and last floret to open in a capitulum, capitula should be harvested 50 days after anthesis for good seed quality and to prevent shattering.**

In seed production, the time of harvest is a critical factor determining seed yield and quality. If harvested too early, a high percentage of immature seeds may exist, while if too late, shattering can occur and field weathering may deteriorate mature seeds. Optimal timing of harvest is determined by the time after pollination when seeds can germinate and grow normally. Relationships between seed maturity and germination have been studied in several crops (Cochran, 1943; Robertson and Curtis, 1967; TeKrony et al., 1984; Wellington, 1956). Seed maturity is commonly assessed by the change in color of the pericarp, seed coat, or the seed itself. The relationships between maturity and seed color have been investigated in several crops (Crookston and Hill, 1978; Hanft and Wych, 1982).

In zinnia capitula, new florets open successively over 20 to 25 days (Miyajima and Nakayama, 1994). Assuming that florets are pollinated at anthesis, seeds (technically achenes) of diverse ages are mixed in a capitulum, the harvested unit. Harvesting the capitula early would include seeds with differing maturities. Conversely, capitula with completely matured seeds are prone to shatter due to wind, physical contact, or harvest method, resulting in a serious loss of seed.

The objectives of this study were to investigate the effect of days after pollination (DAP) on the seed performance of zinnias and to determine the optimum harvest time by evaluating germination and plant growth. Also in this study, the changes in the pericarp color of the achenes were evaluated as they were related to DAP. Since fertilization occurs mostly within an hour after pollination in zinnias (Boyle and Stimart, 1986), days after fertilization are used depending on the cases in the following.

Received for publication 15 Feb. 1996. Accepted for publication 29 Nov. 1996. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Materials and Methods

This study was conducted at the farm of the Faculty of Agriculture of Shinshu Univ., Nagano Prefecture, Japan, in 1993 and 1994. The inbreds used were 'Kumamotonokagayaki' (Kk), pumila double (Takii Seed Corp., Kyoto); 'Goldenball' (Gb), pumila double (Takii); and 'Purple Gem' (PG), pompon (Sakata Seed Corp., Kanagawa). These cultivars were sown in a medium consisting of 1 peat moss : 1 sand : 1 *kuroboku* soil (volcanic ash soil) (by volume) with a 14N–5.2P–11.6K coated fertilizer (8 $g \cdot L^{-1}$) in 1.2-L polyethylene pots on 6 Apr. 1993. The plants were thinned to one per pot. A 14N–2.2P–5.8K soluble fertilizer (5 $g \cdot L^{-1}$) was applied to the plants once a week after emergence. Thirty seedlings from each cultivar were planted into two plastic film greenhouses at a spacing of 0.8 m between seedlings in a row and 1.0 m between rows for each cultivar. A 14N–5.2P–11.6K coated fertilizer (150 $g \cdot m^{-2}$) was preplant-broadcast and incorporated. The sides of the greenhouses were open throughout the study (temperature range of 10–35 °C). In July and Aug. 1993, ray florets on newly opened capitula were cross-pollinated by hand within each cultivar. Each capitulum was labeled with the day of pollination. Pollinated capitula were not used for subsequent pollinations. Pollinations were conducted daily during 60 days except during rain.

To obtain seeds with various intervals between pollination and harvest (DAP), harvest of pollinated capitula started 30 days after the first pollination, thus, one to five labeled capitula were collected from each plant every 3 days without reference to the date of pollination. The random collection was done to minimize the effects of any differences in weather or temperature under which the seeds grew.

Pollinations were continued during the collection of capitula. The length, width, and weight of fertilized ovules or embryos harvested 0 to 35 DAP were measured to monitor the growth of seeds after fertilization. Twenty ovules (or embryos) at each DAP, two per capitulum from 10 separate plants of each cultivar, were measured. The remainder of the harvested seeds were removed from the receptacles and were grouped by the days from pollination to harvest in each cultivar. Each group of seeds was placed in an envelope. Envelopes were stored at 30% to 35% RH in a desiccator that was set in a unheated room at 0 to 25 °C. Visual determination of pericarp color and germination tests were conducted in Feb. 1994. Germination tests were performed as follows: three replications of 20 seeds from each group (envelope) were placed on a sheet of filter paper in 9-cm petri dishes. Distilled water (5 mL) was added to each Petri dish. Seeds were germinated at 20 ± 1 °C and radicle emergence, defined as germination, was counted daily. Percent germination (G) and days to germination were calculated. Prelimi-

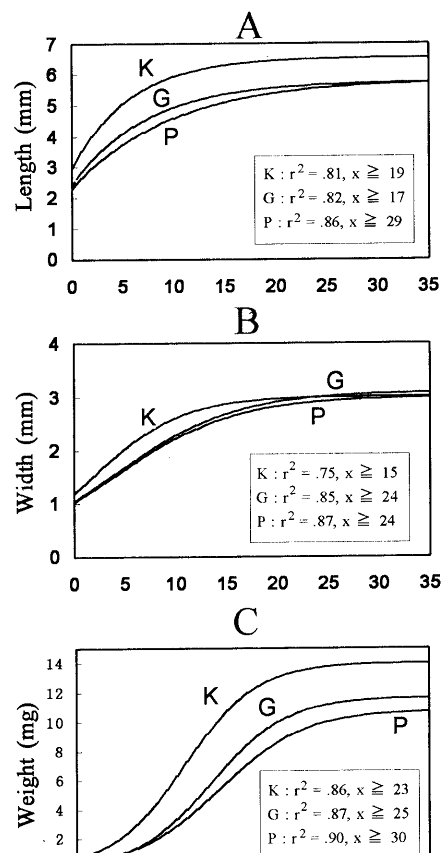

Fig. 1. Postfertilization growth of ovules of zinnias. (**A**) length, (**B**) width, (**C**) weight. 'Kumamotonokagayaki' (K), 'Goldenball' (G), and 'Purple Gem' (P). All regressions are significant at $P \leq 0.01$. The ranges of X written in a box at the lower right corner in each figure denote ranges where Y is independent of X ($P > 0.05$).

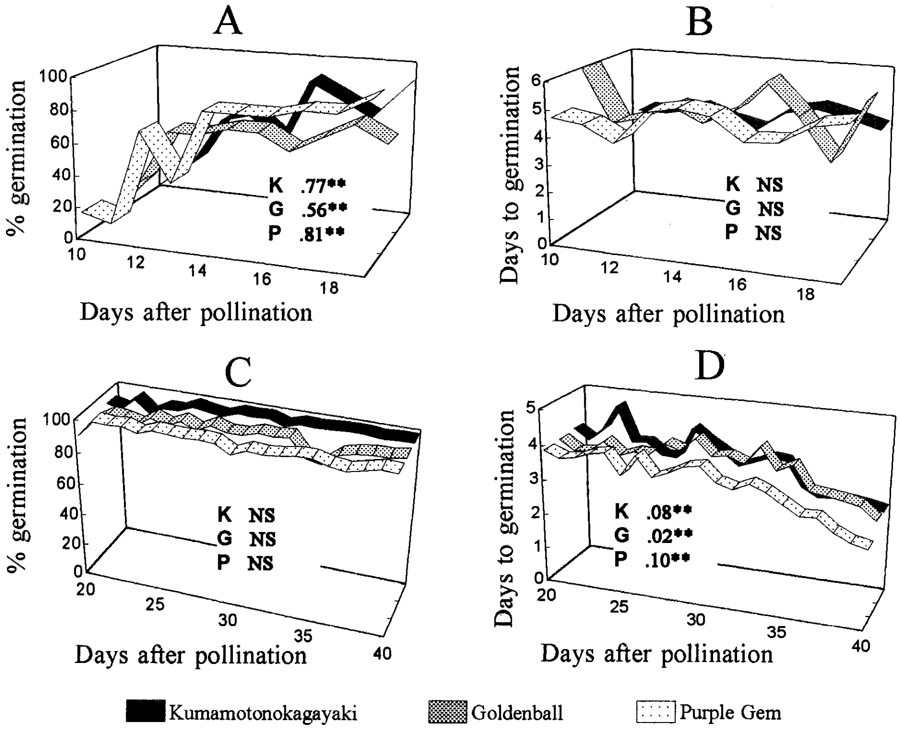

Fig. 2. Germination characteristics of zinnia seeds as influenced by the days after pollination. (**A**) Percentage germination and (**B**) the days to germination for the seeds harvested within 19 DAP. (**C**) Percentage germination and (**D**) the days to germination for seeds harvested 20 to 40 DAP. K, G, and P denote 'Kumamotonokagayaki', 'Goldenball', and 'Purple Gem', respectively. Double asterisks denote that Y is dependent on X at $P \leq 0.01$. Figures on the left sides of asterisks denote coefficients of determination of the linear regressions.

nary results indicated that seeds with >90% germination were obtained when harvested more than 20 DAP in all cultivars. The growth of plants were investigated for the seeds harvested at 20 to 40 DAP. These seeds were sown in vermiculite in 0.3-L polyethylene pots on 26 May 1994. The plants were thinned to one per pot. A 14N–2.2P–5.8K liquid fertilizer (5 $g \cdot L^{-1}$) was applied to the plants once a week after emergence. Seedlings of each cultivar/DAP combination were planted in a completely randomized design with eight plants per experimental plot; but due to death, 5 to 7 remained in some experimental plots at harvest. Spaces between plants and rows were 0.3 m. A 14N–5.2P–11.6K coated fertilizer (150 $g \cdot m^{-2}$) was preplant-broadcast and incorporated. The days to first capitulum anthesis were recorded for each plant. On 10 Aug., plants were harvested and the following traits were measured: height from soil level to the first capitulum and to the highest point of the plant, number of shoots generated from the primary shoot, diameter of the first capitulum, and shoot fresh weight. The best-fit, nonlinear regression models were determined for the growth of the fertilized ovules (or embryos) of each cultivar using the least square methods.

The best fit curves were $y = K - ab^x$ for length and $y = \gamma/[1 + \alpha \exp(-\beta x)]$ for width and weight where K and γ are the upper limits; a, b, α, and β are parameters. In each cultivar, the statistical dependence of arcsin-transformed G, days to germination, and growth of plants on the days from pollination to harvest of the seeds were tested. G and days to germination were evaluated separately for seeds harvested <20 DAP and ≥20 DAP. In the case where the regressions were significant ($P \leq 0.05$), the coefficients of determination of the regressions were determined.

Results and Discussion

The growth of ovules (or embryos) after fertilization fit the exponential and logistic curves as indicated by the high coefficients of determination. According to these regression equations, the length of fertilized ovules (or embryos) rapidly increased immediately after fertilization and then gradually slowed in all cultivars (Fig. 1). The increase in length was largest between 0 and 10 DAP and it plateaued before 20 DAP for Kk and Gb while it continued until about 30 DAP for PG. In all cultivars, the width of the fertilized ovules increased at a constant rate until 15 DAP and then the increase gradually terminated. In all cultivars, the weight of the ovules rapidly increased between 5–20 DAP and then the increase slowed between 20 to 30 DAP. Thus, all cultivars showed a similar pattern of embryo growth, but the periods in which they grew differed between the pumila-double and pompon cultivars.

Two cultivars were able to germinate 10 DAP (Fig.2) when the embryos were still growing (Fig. 1). G of seeds harvested at 10 DAP were 5% and 15% for Gb and PG, respectively. G increased for seeds as they increased in age between 10–19 DAP, while days to germination was not affected. In all cultivars, G was similar among seeds harvested at 20 DAP or more (Fig. 2). Days to germination decreased with an increase in the time from pollination to harvest. For the growth of plants grown from the seeds harvested between 20 and 40 DAP, days to anthesis of the first capitula and height to the first capitula became fewer with the increase in DAP for Kk and PG (Fig. 3 A and B). The number of shoots became fewer with the increase in DAP for Gb and PG (Fig. 3D). However, the low coefficients of determination indicated that the significance of regressions was slight. In all cultivars, the diameters of the first capitula and heights of the plants were independent of the DAP of the seeds (Fig. 3 C and E). Shoot fresh weight decreased with an increase in the DAP of seeds for PG (Fig. 3F). Thus, plants grown from seeds harvested at fewer DAP were not inferior to those grown from seeds harvested at more DAP within the range of 20–40.

The majority (>90%) of the pericarps of zinnia seeds harvested within 30 DAP were green in all cultivars studied . Pericarps of seeds harvested at 30 to 35 DAP were green, partially brown, or completely brown. The growth of plants from seeds harvested at various DAP was not influenced by pericarp color. The harvest of seeds even at 20 DAP, when the pericarp color was completely green, did not affect the performance of the seeds except for a slight delay in germination when compared with the seeds harvested when the pericarps were partially or completely brown. Therefore, the complete loss of green pigment from the pericarp is not a determining factor in the time for harvest in zinnia seeds.

Modern plug growing operations require seeds with high quality. The results of this study demonstrated that seeds harvested up to 19 DAP are not recommended for commercial use, but that high seed quality can be obtained from 20 to 40 DAP. Since zinnia seeds are harvested by the capitulum unit, it is important to determine the best time for harvest of capitula. In a capitulum, a 20- to 25-day difference as an average has been reported between the first and last florets to open (Miyajima and Nakayama,1994). However, >30-day difference in floret opening has been measured in some capitula because of the deviations from the average (D. Miyajima, unpublished data). However, the possibility of shattering of early set seeds increases if the harvest of capitula is late. Therefore, harvest of capitula at 50 days after anthesis is recommended as a compromise between the loss of seeds produced at the early stages and maturity of seeds produced from the last florets to open.

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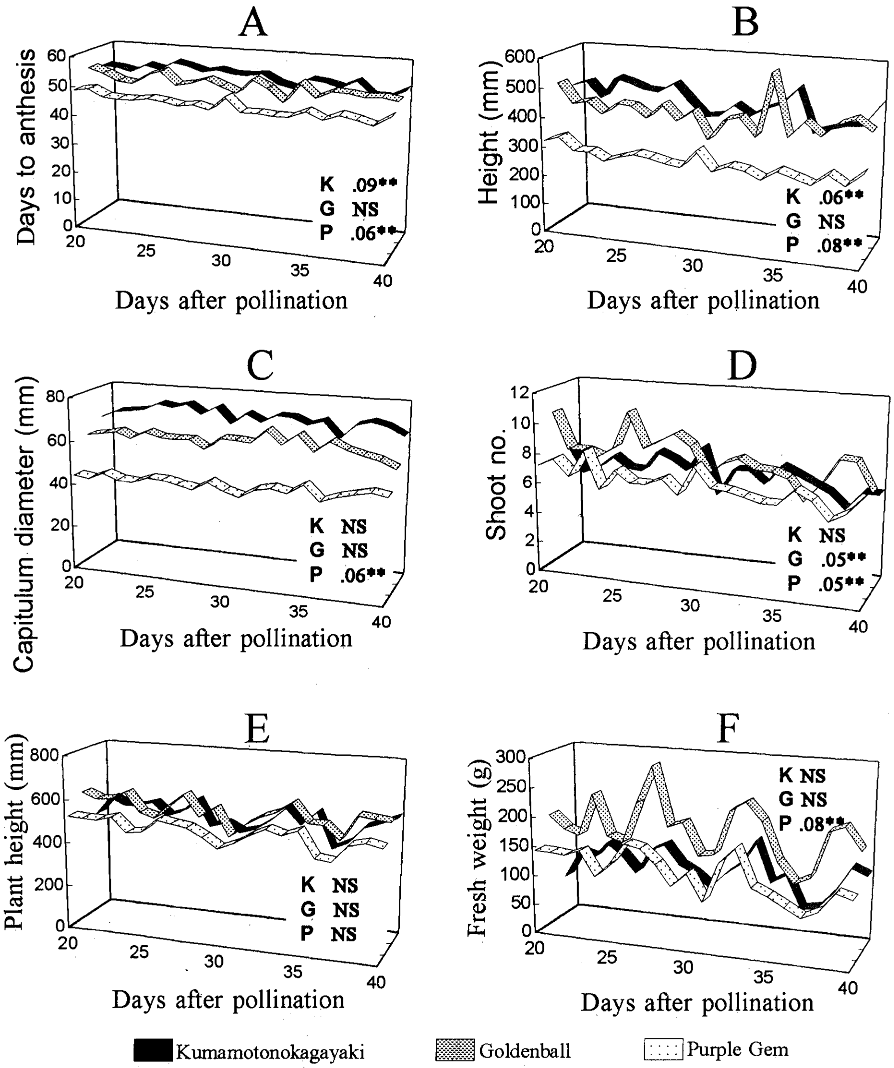

Fig. 3. Growth of zinnia plants generated from the seeds harvested 20 to 40 days after pollination: (**A**) Days to the first capitulum anthesis, (**B**) height to the first capitulum, (**C**) diameter of the first capitulum, (**D**) number of shoots generated from the primary shoot, (**E**) height of plants, (**F**) top fresh weight. These traits, except (**A**), were measured 76 days after seeding. K, G, and P denote 'Kumamotonokagayaki', 'Goldenball', and 'Purple Gem', respectively. Figures with asterisks denote coefficients of determination of the linear regressions. Double and single asterisks denote that Y is dependent on X at $P \leq 0.01$ and 0.05, respectively.