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SOME APPLIED ASPECTS OF GIBBERELLIC ACID IN BARLEY AND WHEAT*

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Spraying of barley spikes, before grain development or at stages during seed maturation, with 500 ppm aqueous solution of gibberellic acid broke the characteristic seed dormancy of freshly harvested barley seeds. Seeds so obtained produced more vigorous seedlings than did the seeds from unsprayed spikes. In a preliminary pot trial, soaking of wheat seeds for 24 hr before seeding in 500 ppm aqueous solution of gibberellic acid showed an increase in yield of late sown wheat as compared to the yields obtained from dry-sowing and transplanting methods recommended for late sown wheat in West Pakistan.

Freshly harvested seeds of barley showing characteristic dormancy require a maturation or after-ripening period before prompt germination can occur. This after-ripening period may vary from 2 weeks to 9 months in barley.[1] Breeders anxious to grow as many generations in as short a time as possible are faced with the need for overcoming fresh seed dormancy. Another inconvenience experienced with such dormant seeds is in their failure to sprout when a test is made to determine their viability soon after the harvest. While a relationship between a post-harvest dormancy and gibberellic acid is recognized in harvested or air-dried seeds[2,3,4] very little is known about the possible effects of its application at stages during seed maturation in cereals. An attempt, therefore, was made in the first part of this work to study the effects of gibberellic acid application at stages during seed maturation on fresh seed dormancy and growth of the seedlings emerging from these seeds in barley.

Occasionally, wheat has to be sown late on large areas of West Pakistan due to the failure of timely rains or inadequacy of irrigation water for preparation of moist seed bed at the right time. This results in considerable reduction in acre-yield in such late sown areas. This reduction in yield is attributable to the availability of a relatively shorter growing period resulting in decreased vegetative growth and limited development of other-yield components. Gibberellic acid has been reported[5] to stimulate vegetative growth of many cereals and grasses especially at times of normally slow growth. It has also been reported[6] that many of the cold-requiring steps of development in many plant species will be satisfied with a gibberellin treatment. Hence, it was contemplated in the latter part of this work to gather information whether gibberellic acid treatment could increase the yield of late sown wheat planted in January), either through stimulation of its vegetative growth or possibly by making up its low temperature requirement that would have been obtained if the crop were sown normally in October–November. Simultaneously gibberellic acid treatment was compared with the dry sowing and the transplanting methods which have been reported to improve the yield of wheat under late sown conditions in West Pakistan.[7]

Materials and Methods

The work relating to barley was initiated in 1967 at the University of California, Davis. A mildew-resistant type of Atlas barley, designated UCD 2010, was grown in greenhouse in 15-cm pots filled with a mixture of two-thirds loam soil and one-third sand. Four plants per pot, watered as necessary to prevent moisture stress, were grown to maturity. Greenhouse temperatures were maintained near 21°C day and 15°C night. The age of the caryopsis during maturation was stated in terms of days after awn emergence of the spike bearing the caryopsis. A tag bearing the date of awn emergence was placed on each jointing culm. The spikes at 21 days after awn emergence were sprayed daily for 3 days with 500 or 1000 ppm aqueous solution of gibberellic acid. Seed was harvested when all green coloration had left the spike. Immediately upon harvest replicated 50-seed samples were planted at 1.5-cm depth in moist sand and germinated in a growth chamber at constant 15° and 20°C as well as alternating temperatures of 15° and 20°C with 8 hr of low intensity illumination daily. Germination was based on seedling emergence counts recorded for 14 days.

Subsequently the study was continued at the West Pakistan Agricultural University, Lyallpur, where seeds of barley Type-5 growing under the natural conditions in the field were sprayed with 500 ppm aqueous solution of gibberellic acid at 7, 14, 21 and 28 days following awn emergence. The seed was germinated at room temperature, on moist filter paper in 9-cm petri dishes 1 day

*The work relating to barley was partly carried out by the senio author (R.A.K.) in the Department of Agronomy, University of California, Davis.

after harvest as well as after 7 month of storage. Seedling growth was evaluated by measuring root, shoot, and coleoptile lengths at 7 days after planting using the slanted substrate technique. Twenty seeds were planted in a row at the mid section of a moist horizontal blotting paper. A single ply of thin dry cellulose tissue was placed over the seed. A fine mist of water was sprayed over the tissue. The clinging moist tissue held the seeds firmly in place so that the substrate could be slanted to any position. The embryo ends of seeds faced downward. For support the blotting paper was placed on a $26\frac{1}{4} \times 20$ cm rectangular glass plate. A wooden rack was used to hold the slanted substrate sheet with the basal portion in a water reservior. The plumules grew straight upward and the radicles downward along the slanted substrate. The shoot growth was measured from the hypocotyl to the tip of the first leaf and the root length from the point of emergence to the tip of the root. Coleoptile length was measured at the time of first leaf emergence.

To study the effect of gibberellic acid on late sown wheat and its comparison with the dry sowing and transplanting methods, 8 plants per pot of variety C273 were grown outdoors in 24-cm pots filled with loam soil. The seeds pre-soaked for 24 hr in an aqueous solution of 500 ppm of gibberellic acid were sown in 3 sets of 4 pots each. Subsequently one spraying of the same strength of gibberellic acid was applied at three-leaf stage in one set, at tillering in the second set, and no subsequent spraying was done in the third set. In the case of dry sowing, the seed was seeded in dry soil and the pots were watered afterwards. For transplanting, November and December raised seedlings in the field were transplanted in pots. All the replicated seeding and transplanting treatments were done on January 7 as against October–November which is the normal sowing time of wheat in this region. The November-raised seedlings had formed 4 to 5 tillers, while the December-raised seedlings were at three-leaf stage at the time of transplanting. Sixty pounds of urea nitrogen for 2×10^6 lb of soil was applied to each pot (30 lb soil) 3 weeks after seeding or transplanting. Observations were recorded for the number of tillers, number of spikes, and number of grains per spike, and the yield per pot under each treatment. The crop was on April 30. Duncan's multiple range test was harvested employed for determing statistical significance among the treatment means.

Results and Discussion

Effect on Germinability and Seedling Growth in Barley

Greenhouse-grown 'Atlas' barley, designated UCD 2010, matured seed some 30 days after awn emergence. Gibberellic acid was applied at 21 days of awn emergence in concentrations of 500 and 1000 ppm. The germination test at 20°C was commenced 1 day after harvest. The germinability of four 50-seed samples is presented in Fig. 1. The percentage of germination in the gibberellic acid-sprayed seeds at harvest was significantly higher than that of the unsprayed. 500 ppm aqueous solution appeared to be sufficient for maximum effectiveness in breaking fresh seed dormancy.

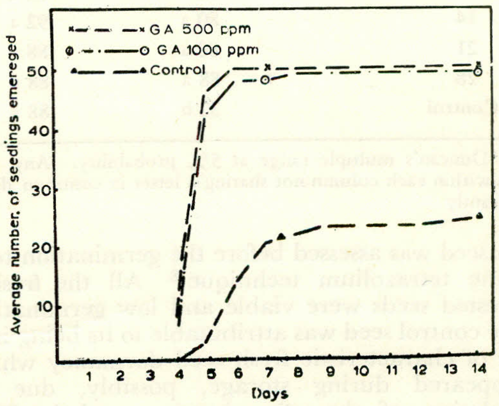

Fig. 1.—Emergence of seed planted 1 day after harvest, following gibberellic acid spray at 21 days after awn emergence. Each value is the mean of four 50-seed lots tested at 20°C.

Germinating the control seed at 15°C or alternating temperatures of 15°and 20°C did not improve its germinability at harvest over that obtained at 20°C. These results suggested that gibberellic acid will overcome fresh seed dormancy in those barley varieties which, immediately upon harvest, may not give satisfactory germination at 15° or 20°C due to relatively deeper dormancy of their seeds.

The best stage of seed maturation for gibberellic acid treatment and the subsequent effect on the seedling growth were studied by using a standard variety of barley (type 5) grown in West Pakistan. Spikes of this variety growing under the natural conditions in the field were sprayed with gibberellic acid at stages during seed maturation. Spikes treated at 7 to 14 days after awn emergence had not yet formed seed which developed during the third week following awn emergence. The seeds matured 43 days after awn emergence and their percentage of germination at harvest as well as after 7 months of storage at room temperature are given in Table 1.

Once again, the control seed showed a significantly lower germination at harvest than the gibberellic acid treated seeds. The viability of the

TABLE 1.—EFFECT OF GIBBERELLIC ACID SPRAYING AT DIFFERENT STAGES DURING SEED MATURATION ON GERMINABILITY OF BARLEY (TYPE-5), SEEDED ONE DAY AFTER HARVEST AND AFTER SEVEN MONTHS OF STORAGE AT ROOM TEMPERATURE.

Stages of gibberellic acid spray (500 ppm) (days after awn emergence)	Germination % at 7 days after planting	
	Fresh seed	Stored seed
7	84 a*	94 a
14	80 a	92 a
21	88 a	88 a
28	88 a	88 a
Control	32 b	88 a

*Duncan's multiple range at 5% probability. Any two means within each column not sharing a letter in common differ significantly.

fresh seed was assessed before the germination test, by the tetrazolium technique.[8] All the freshly harvested seeds were viable and low germination of the control seed was attributable to its being in a state of characteristic fresh seed dormancy which disappeared during storage, possibly, due to completion of the after-ripening period. This after-ripening period may vary from 14 days to 9 months in different barley species.[1]

These results suggested that exogenous application of gibberellic acid to the spikes even before seed formation or at stages during seed maturation could overcome the fresh seed dormancy in barley. The exact mechanism as to how this is done is not well understood. Presence of a relatively higher level of metabolic inhibitors in the non-after ripened seeds is often recognized to cause dormancy in such seeds. Exogenously applied gibberellic acid, possibly had some modifying effect on the effective inhibitor level. This view is supported by the observations of Naylor and Simpson.[9] They have reported that natural inhibition of germination in *Avena fatua* involves restriction of the accumulation and utilization of sugars; both these metabolic blocks are independently overcome by exogenous gibberellic acid. Another reason of faster emergence in the gibberellic acid treated seeds could be the increased production or activity of the hydrolytic enzymes involved in the germination process. This belief is strengthened by the work of Briggs,[10] Chrispeels and Varner,[11] and Jacobsen and Varner.[12] They have shown that the effect of gibberellic acid is to promote the simulataneous synthesis and secretion of a group of hydrolases such as α-amylase, phosphatase, β-glucanase, protease and ribonuclease in barley endosperm.

The immature seeds sprayed with gibberellic acid while still on the parent plant matured more uniformly than the control seeds. Seven-day old seedlings from the former seeds grown on slanted substrates were more vigorous and had greater root, shoot, and coleoptile lengths as compared to those of the control seeds (Table 2). Measurable difference in growth of the young plants from the treated and non-treated seeds grown outdoors in pots was also noticeable (Figure 2). Hashmi[13] also found that one spray of gibberellic acid at 21 days after awn emergence was enough to overcome fresh seed dormancy and to induce greater seedling vigour.

Greater root, shoot, and coleoptile elongation of the seedlings emerging from the gibberellic acid treated seeds suggested that gibberellic acid was in some way involved in stimulating the activity of the root and shoot meristems resulting in the vigorous growth of these seedlings as growth is the result of the meristematic activities. Formation

TABLE 2.—SEEDLING GROWTH AT SEVEN DAYS AFTER PLANTING OF THE SEEDS TREATED WITH GIBBERELLIC ACID AT DIFFERENT STAGES DURING SEED MATURATION.

Stages of gibberellic acid treatment (500 ppm) (days after awn emergence).	Average* length (cm)		
	Root	Shoot	Coleoptile
7	17.04a†	19.02 a	5.7 a
14	15.23 a	17.27 a	5.6 a
21	15.23 a	20.32 a	5.7 a
28	16.90 a	17.12 a	5.6 a
Control	10.97 b	13.81 b	4.5 b

* Average of 20 seedlings.
† Duncan's multiple range at 5% probability. Any two means within each column not sharing a letter in common differ significantly.

Fig. 2.—(From left to right) Young plants from the gibberallic acid treated and non-treated seeds, respectively.

of new meristematic regions and stimulation of mitotic activity in apical meristems resulting in increased elongation growth due to gibberellin has also been reported by Sachs.[14]

These findings have an added significance, especially under the rain-fed areas of West Pakistan where seed has to be placed relatively deeper for providing it with optimum moisture for germination. The vigorously growing seedlings with greater coleoptile length obtained from the gibberellic acid treated seeds may result in better emergence and seedling establishment under relatively deeper seeding because favourable coleoptile elongation is a measure of superior emergence and seedling establishment.[15,16]

Effect on the Late Sown Wheat

The results of gibberellic acid treatment, dry sowing and transplanting on the yield of wheat sown late on January 7 and harvested on April 30, are given in Table 3.

Soaking seed for 24 hr in 500 ppm aqueous solution of gibberellic acid, before seeding, increased the yield of late sown wheat as compared to the dry-sowing and the November or the December-raised transplants. The increase in yield of gibberellic acid treated seeds over the November-raised transplants was, however, not statistically significant. It was due to the reason that this pot study was initiated in early January when December or November-grown seedlings in pots could not be raised for transplanting. It was due to the reason that this pot study was initiated in early January when December or November grown seedlings in post could not be raised for transplanting. Consequently, seedlings of this age already growing in the field had to be used as transplants. Thus, the November-raised transplants used in this study had already formed 4 to 5 tillers and had the additional advantage of growing under the field conditions for about 42 days. Despite these advantages of the transplant crop, statistically similar yield given by the crop from the gibberellic acid treated seed is a remarkable performance. It was also interesting to observe that only the November-raised seedlings when transplanted in early January showed their superiority over the dry seeding practice, suggesting that for the transplanting method of sowing wheat recommended under very late sown conditions in this region, transplants raised during the normal sowing time of the crop should be used.

TABLE 3.—COMPARATIVE EFFECTS OF GIBBERELLIC ACID TREATMENT OF SEEDS, DRY SOWING, AND TRANSPLANTING, ON THE GRAIN YIELD OF LATE SOWN WHEAT (C273) AT LYALLPUR, WEST PAKISTAN.

Treatment	Yield per pot (g)
1. Seed pre-soaked in gibberellic acid	21.3 a*
2. As in no. 1 + one subsequent spraying at 3-leaf stage	12.41 b
3. As in no. 1 + one subsequent spraying at tillering	13.75 b
4. Dry sowing	12.26 b
5. November-raised transplants.	28.48 a
6. December-raised transplants	13.75 b

* Duncan's multiple range at 1% probability. Any two means which do not share a letter in common differ significantly.

The increase in yield of the gibberellic acid treated seed was attributable to greater tillering and spike formation (Fig. 3). However, when the seedlings from the gibberellic acid treated seeds were subsequently sprayed at the three-leaf stage or at tillering it did not improve the yield over dry sowing or transplanting methods; because subsequent spraying with gib-

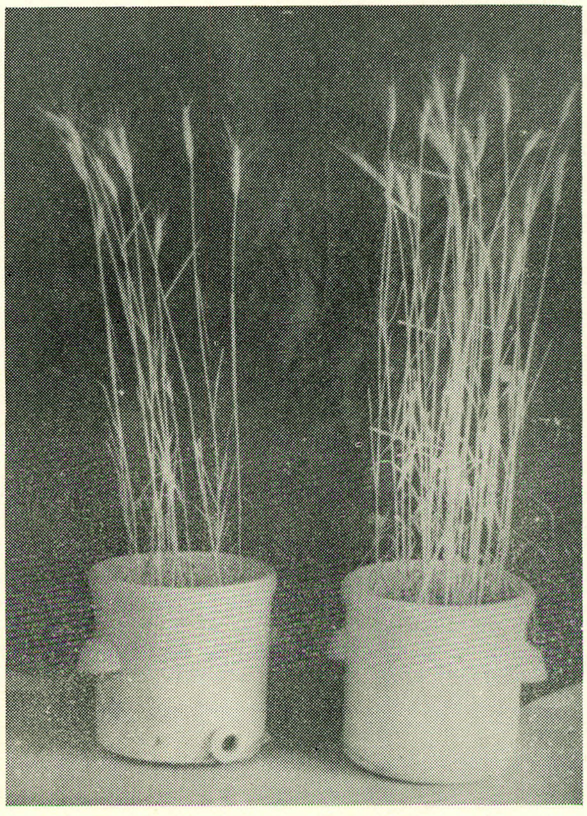

Fig. 3.—Increased tillering and spike formation in the case of gibberellic acid treated seed (right) as compared to the untreated seed or dry sowing (left).

berellic acid at the three-leaf stage caused rapid shoot elongation with weaker base resulting in severe lodging of the young seedlings. A similar treatment at the tillering stage resulted in the plants having thinner and taller culms bearing spikes with reduced number of grains. These results suggest that the seed treatment may be more effective than the subsequent applications of gibberellic acid for improving performance of the late sown wheat under the conditions obtaining in West Pakistan. The preliminary information gathered as a result of these studies may be useful in practical agriculture.

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