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Effect of Chemicals on the Carbohydrate Contents of Pumpkin (Cucurbita pepo) Seeds During Germination

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The effect of pre-soaking treatments of optimum concentration of fertilizers on the carbohydrate contents *viz.* total sugar, reducing sugars, starch and amylose of *Cucurbita pepo* (pumpkin) seeds during germination periods up to 12 days were studied. Variations in the contents of carbohydrate during growth periods are explained on the basis of mutual effect of metabolites and of certain related enzymes over and above the effect of method of pre-soaking treatment and of chemicals on the mitochondrial function. It is also reported that the vegetative growth and the nutritive value of mix treatment are higher than in the other cases studied.

Die Wirkung von Chemikalien auf die Kohlenhydratgehalte von Kürbissamen (*Cucurbita pepo*) **während der Keimung.** Die Wirkung von Einweichbehandlungen mit optimalen Konzentrationen an Düngemitteln und Wachstumsregulatoren, einzeln oder vermischt, auf die Kohlenhydrate wie Gesamtzucker, reduzierende Zucker, Stärke und Amylose von *Curcubita-pepo*-Samen (Pumpkin) innerhalb von Keimperioden bis zu 12 Tagen wurde untersucht. Änderungen der Kohlenhydratgehalte während der Wachstumsperioden werden auf der Grundlage der gegenseitigen Einwirkungen von Stoffwechselprodukten und von bestimmten, mit ihnen im Zusammenhang stehenden Enzymen über das Verfahren der Einweichbehandlung hinaus und der Chemikalien auf die mitochondriale Funktion erklärt. Es wird auch berichtet, daß das vegetative Wachstum und der Nährwert bei gemischter Behandlung höher sind als bei den anderen untersuchten Behandlungsarten.

1 Introduction

It is known from literature that carbohydrates play a principal role in both the metabolism and the structure of plants. A great deal of work on chemical changes occurring in carbohydrates, fats and proteins of varied seeds during germination, has been reported in literature [1–3]. The pre-soaking effects of various growth regulators and fertilizers on the carbohydrate contents of varied seeds during growth periods are also visualised in literature [4–8]. *Ayako* [9] has studied the distribution of free sugars in the organs of various vegetable plants of the cucurbitaceae family during germination. *Videnin* and *Rodionov* [10] have studied the effects of soaking pumpkin, cucumber and tomato seeds in KBr solution, hydroquinone, gibberellin and oil growth substances, on growth. The results *viz.* growth and enzyme activity of the treated seeds were compared with those of dry seeds and the seeds soaked in water. *Pervova* and *Palladina* [11] have studied the effect of gibberellic acid on carbohydrate contents of the vegetative organs of squash and potato. *Oza* et . al. [6] have studied the effect of various types of fertilizers and of growth regulators on carbohydrate contents of *Lagenaria vulgaris* seeds during germination. *Singh* and *Singh* [12] have studied the effect of pre-soaking treatment of nitrogenous solution on the germination and early seedling growth of pumpkin seeds. *Splittstoesser* and *Stewart* [13] have studied the distribution and isoenzymes of asparatase amino transfer in cotyledones of germinating pumpkins. *Hara* et al. [14] have studied the pumpkin seed globulin alterations during germination. *Reilly* et al. [15] have studied solubilization and degradation of pumpkin seed globulin during germination. *Vanousova* et al. [16] have studied the distribution and translocation of calcium in young pumpkin. *Dvork* and *Jana* [17] have studied calcium nutrition and the uptake of ions into the roots of pumpkin plants. *Pichl* and *Svatua* [18] have marked the growth of wheat, pumpkin and pea in calcium or potassium deficiency.

From the above review it seems that most of the work reported in literature with respect to effect of growth regulators and fertilizers on the chemical constituents of the seeds is mainly

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confined to seeds other than pumpkin. Systematic study with respect to effect of pre-soaking treatment of various types of fertilizers and of growth regulators on the vegetative growth and the chemical constituents has not so far come across.

In the present investigation, an attempt is made to study carbohydrate contents of the seeds, treated with distilled water (i), optimum concentration of various fertilizers (ii), and growth regulators (iii) over and above the dry seeds as such (control), germinated for different periods in controlled condition. The carbohydrate contents of the seeds treated with combined effect of useful optimum concentrations of the fertilizer and growth regulator, and germinated at optimum pH of the medium, are also determined in order to know how mix treatment affects the vegetative growth and thereby the metabolites (*viz.* nutrients) of the seedlings.

2 Experimental

Seeds utilized for the work were of locally available pumpkin (*Cucurbita pepo*) of the Saurashtra region. The mode of treatments and the germination employed in the present work were as per the procedure adopted in our previous work [5, 6]. The following optimum conditions were set up after conducting a number of experiments with respect to variation in (i) soaking periods, (ii) concentration of the fertilizers and the growth regulators and (iii) the pH of the medium, for good vegetative growth in cold sterilized quartz sand under optimum light conditions in a laboratory environment at a constant temperature of 29 ± 1 °C.

(1) *Soaking period*: 2 h
(2) *pH of the medium*: 7.0
(3) *Concentrations of chemicals used during soaking treatments*

(A)	Names of fertilizers	conc. in mg/100 ml
(i)	Potassium chloride (PC)	90
(ii)	Urea (Ur)	150
(iii)	Tri-Sodium Phosphate (SP)	100

(B)	Names of growth regulators	conc. in mg/100 ml
(i)	Gibberellic acid (GA)	30
(ii)	Ascorbic acid (AA)	90
(iii)	Maleic Hydrazide (MH)	50
(iv)	Suphanilamide (SA)	50

(C)	Names of ingredients of mix treatment	
(i)	PC + AA (MT)	90 + 90

The control and the glass distilled water treated seeds were also germinated under the same conditions *viz.* medium, light and temperature in order to know the effects of various treatments and the effect of method giving treatments to the seeds on the above referred entities. All the seeds treated and the control were weighed individually before placing for germination in a sand bed to express the results of the samples collected on the basis of 1 g original weight of the seeds, which is a definite quantity, as it does not vary with the % moisture of the seedlings. During germination distilled water, obtained from all glass joint apparatus, of pH 7.0 was poured.

Four sets of seedlings, each one in twenty numbers, of each treatment, were removed from the sand bed at the end of a definite period of germination (0, 1, 2, 4, 5, 6, 7, 8, 10 and 12 days). The seedlings were cleansed with cold glass distilled water and dried in a hot air oven kept at 80 °C.
After extracting oil from the dry seedlings, collected at various periods of germination, with petroleum ether (60 – 80 °C), the residual plant materials (cakes) were stored in cold until ready for assay. All the chemicals used in the estimation of carbohydrate contents were of A. R. quality.
Total sugar, reducing sugars, starch and amylose contents of the cakes collected from treated and untreated seeds and the seedlings were determined using the procedure reported by *Vyas* et al. [5].

3 Results

Results reported in the present work Figures 1 to 8 are the average mean of the four sets and are expressed on 1 g weight of the dried seeds. The standard error of mean (SEM) is determined in each case. Its value varying from ± 0.01 to ± 0.1 at the earlier periods of germination *i. e.* upto 4th day, while at the later periods *i. e.* beyond 4th day its value ranging from ± 0.2 to ± 0.5.

3.1 Total Sugar

Figure 1 represents the comparative study of total sugar of the fertilizer-treated seeds over and above those treated with distilled water and the control seeds at varied periods of germination. The Figure also represents variation in total sugar contents of the seeds treated with mix treatment, of optimum conc. of useful fertilizer and growth regulator, during the germination periods. Figure 2 represents the comparative study of total sugar contents of growth regulators treated seeds over and above the distilled water, the mix treatment treated and the control seeds at various growth periods of the study.

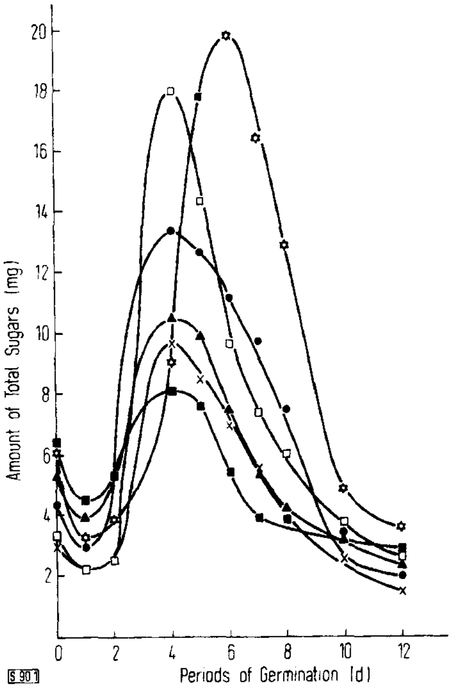

Figure 1. Effect of fertilizers on the contents of total sugars, Treatments: × = Ur; ● = PC; □ = SP; ✡ = MT; ■ = DW; ▲ = Control.

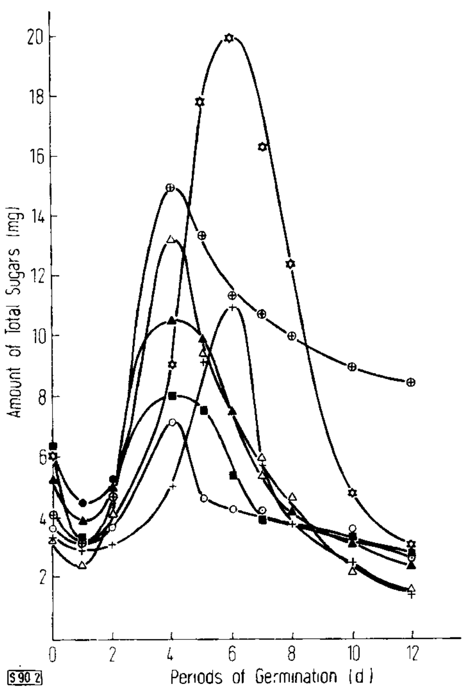

Figure 2. Effect of growth regulators on the contents of total sugars. Treatments: △ = GA; ⊕ = AA; + = MH; ⊙ = SA; ✡ = MT; ■ = DW; ▲ = Control.

The amount of total sugar appearing in Figures 1 and 2 was found to decrease in all the seeds upto the 1st day of germination. From second day onwards its amount was found to increase variedly depending upon the treatment given to the seeds. MT and MH treated seeds had attained maximum total sugar on the 6th day while in other seeds maximum value was obtained on the 4th day of germination. The trend with respect to maximum in Figures 1 and 2 separately, are as follows:

MT > SP > PC > Control > Ur > DW (Fig. 1);
MT > AA > GA > MH > Con > DW > SA (Fig. 2).

The general trend with respect to contents of total sugar at the maxima is as follows:

MT > SP > AA > PC ≃ GA > MH > Con > Ur > DW > SA.

In case of PC and GA treated seeds, the amount of total sugar is almost the same at the maxima, however, the order in sequence is given looking to the actual values.

3.2 Reducing Sugars

Figures 3 and 4 represent the comparative study of reducing sugars of the fertilizers, the growth regulators, the distilled water, the mix treatment treated seeds and the control seeds at varied periods of germination.

Figures 3 and 4 indicate that reducing sugars of all the seeds increased gradually. There is no considerable change in the reducing sugar contents upto 2nd day of germination. All the seeds, treated and the control, except MH and MT treated seeds had maximum reducing sugars on the 4th day of germination. In case of MH and MT treated seeds, maximum reducing sugars was found in between 5th and 6th day and on 6th day respectively during germination and the amount was highest in case of mix treatment. Hypothetical period for the maximum value of reducing sugars in case of MH treatment is shown by dotted line in Figure 4.

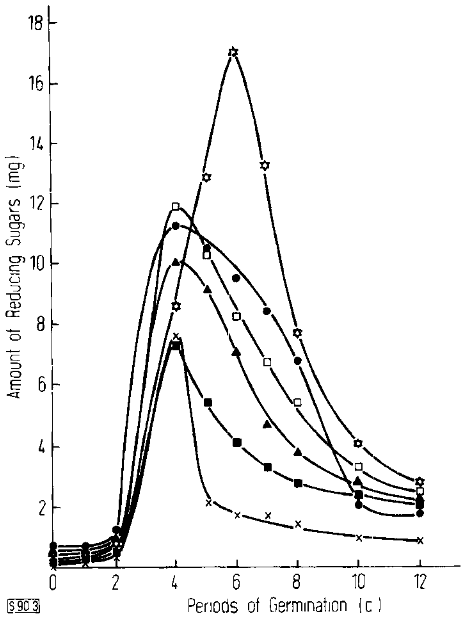

Figure 3. Effect of fertilizers on the contents of reducing sugars. Treatments: × = Ur; ● = PC; □ = SP; ✡ = MT; ■ = DW; ▲ = Control.

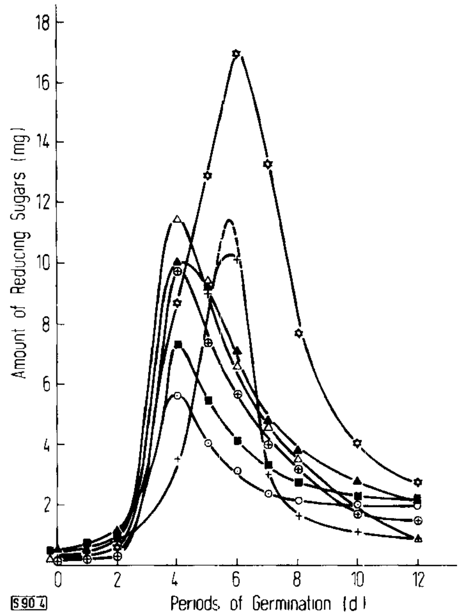

Figure 4. Effect of growth regulators on the contents of reducing sugars. Treatments: △ = GA; ⊕ = AA; + = MH; ⊙ = SA; ✡ = MT; ■ = DW; ▲ = Control.

The trend with respect to maxima in Figures 3 and 4 separately is as under:

MT > SP > PC > Con > Ur ≃ DW (Fig. 3);
MT > GA ≃ MH > Con ≃ AA > DW > SA (Fig. 4).

The general trend with respect to amount of reducing sugar at the maxima in various cases are as follows:

MT > SP ≃ GA ≃ MH ≃ PC > Con ≃ AA > Ur ≃ DW > SA.

In the cases of almost equal amount at the varied maxima, order in the series is given considering actual amount of the reducing sugar for each individual treatment.

3.3 Starch

Figures 5 and 6 represent the variation in starch contents of the fertilizers and the growth regulators treated seeds respectively with the varied periods of germination.
For comparison starch contents of the distilled water treated seeds and the control seeds of the same periods are also shown in each Figure. In all the cases, the starch content was found to decrease (Figs. 5 and 6) on the first day of germination.

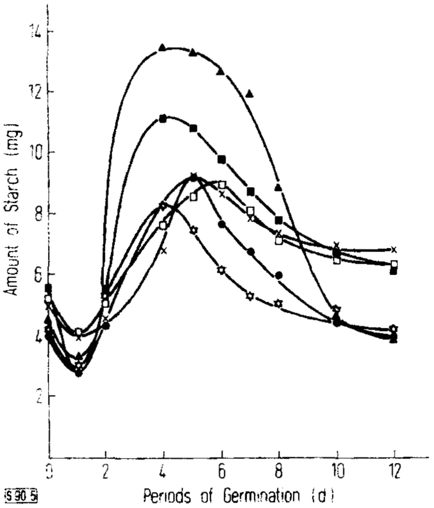

Figure 5. Effect of fertilizers on the contents of starch. Treatments: × = Ur; ● = PC; □ = SP; ✡ = MT; ■ = DW; ▲ = Control.

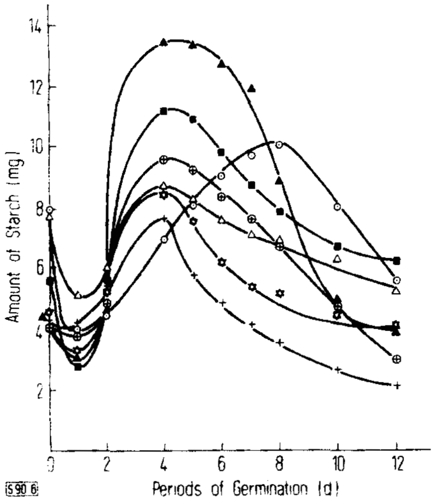

Figure 6. Effect of growth regulators on the contents of starch. Treatment: △ = GA; ⊕ = AA; + = MH; ⊙ = SA; ✡ = MT; ■ = DW; ▲ = Control.

Further, increase in the periods of germination starch content was found increasing, attaining maximum value on the 4th day of germination in all the seeds except PC, Ur, SP and SA treated seeds. PC and Ur treated seeds had attained maximum value on the 5th day of germination while SP and SA treated seeds had attained maximum value on 6th and 8th day of germination respectively. The amount of starch content at the respective maxima of PC, Ur and SP is almost the same, however, in case of Ur and SP there is a gradual decrease in the starch content while in case of PC there is a rapid decrease. The trend with respect to maximum value of starch content in fertilizers treated and growth regulators treated seeds are shown separately as under:

Con > DW > Ur $\simeq$ PC $\simeq$ SP > MT (Fig. 5);
Con > DW > SA > AA > GA $\simeq$ MT > MH (Fig. 6).

The overall general trend with respect to starch contents at the maxima in various treated and untreated seeds is as follows:

Con > DW > SA > AA $\simeq$ Ur $\simeq$
PC $\simeq$ SP > GA $\simeq$ MT > MH.

As usual, in case of almost equal sign, the order in series is given as per the actual amount at the maxima in the specific treatment.

3.4 Amylose

Results of Figures 7 and 8 represent the variation in amylose contents of fertilizers and growth regulators treated seeds, over and above the DW, the MT treated and the control seeds with the periods of germination. The amylose contents of all the seeds increased with the increase in the period of germination. The seeds treated with Ur, AA, GA, DW, MT treatments and the control seeds had attained maximum amylose on the 4th day of germination while PC, SP and SA treated seeds had exhibited maximum amylose on the 6th day of germination. MH treated seeds, had attained maximum value on the 5th day of germination.

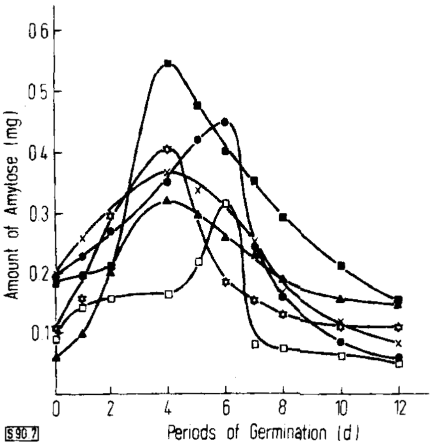

Figure 7. Effect of fertilizers on the contents of amylose. Treatments: × = Ur; ● = PC; □ = SP; ✡ = MT; ■ = DW; ▲ = Control.

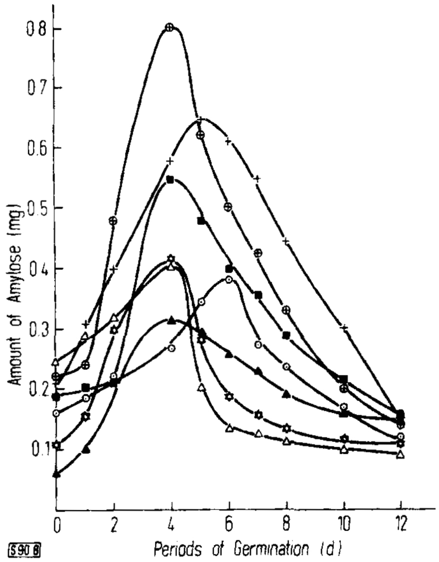

Figure 8. Effect of growth regulators on the contents of amylose. Treatments: △ = GA; ⊕ = AA; + = MH; ⊙ = SA; ✡ = MT; ■ = DW; ▲ = Control.

The trend with respect to amount of amylose at the various maxima of Figs. 7 and 8 are as follows:

DW > PC > MT > Ur > Con ≃ SP (Fig. 7);
AA > MH > DW > MT ≃ GA > SA > Con (Fig. 8).

The overall general trend in the contents of amylose at the maxima in different cases are as follows:

AA > MH > DW > PC > MT ≃ GA >
SA ≃ Ur > Con ≃ SP.

4 Discussion

Decrease in the contents of total sugar and starch on the 1st day of germination is likely to be due to the following reasons.

Under an appropriate environment for germination, the rate of metabolism inside the seed is remarkably accelerated. A great increase in the enzyme activity of the seeds during germination is reported in literature [19]. It is also a known fact that even when photosynthesis is not occurring, plants respire and the reserve materials such as carbohydrates *icluding sugars, their* derivatives and polysaccharides are utilised by respiration.
As per the present observations and the observations marked earlier [5, 6] reducing sugars of all the seeds was found to increase during germination. The decrease in the contents of total soluble sugar upto 1st day (Figs. 1 and 2) and gradual increase in the reducing sugars during initial stages of germination (Figs. 3 and 4) with a decrease in the content of starch on the 1st day (Figs. 5 and 6) clearly suggests that the energy required by the embryo is provided by the stored soluble sugar in the form of reducing sugars but as it can be produced from total sugar and starch, the amount of reducing sugars is found to increase gradually with a remarkable decrease in the contents of total sugar and the starch. Thus, it implies that there is a preferential metabolism of the non-reducing part of the total sugar and of the starch to reducing sugars and the rate of its utilization by the embryo is lower than the rate of production must have resulted in gradual increase in reducing sugars. The observation that the starch is metabolised to a greater extent on the first day of germination is also in agreement with the observations made by *Goswami* et. al. [20] in case of germinating wheat seeds. *Khan* and *Murshed* [21] have also reported that the degradation of starch into sugar is rapid in the begining of germination in general.

From 1st day onwards there is a regular increase in the total sugar and the starch upto 4th day in most of the cases studied and thereafter in the remaining one. The regular increase in total sugar and the starch might be due to the following reasons.
It is marked in the present study that % oil decreases rapidly from 1st day onwards and is maximum in MT treatment during germination [22]. Amylase activity which is known as starch splitting activity, is found maximum on 6th day in most of the cases (PC, Ur, SP, MH, SA, DW and Con) except with GA, AA and MT treatments where it has attained maximum value on 4th day. At the initial stages its value is nearly one third the value at various maxima in most of the cases studied.

From above observations we believe that increase in the contents of starch and total sugar from 1st day onwards may be due to conversion of fats to carbohydrates and as there is no appreciable amount of amylase activity, phosphorylase activity must have played a major role in the increase of starch content as most of the seeds contain starch splitting and starch forming enzyme [23]. The conclusion made by *Murlin* [24], in case of germinating caster bean seeds, that a major part of the fat reserve was converted into carbohydrates, is in agreement with our belief. *Sasaki* [25] has also made the same remark, *i.e.* that the loss in oil corresponded to the gain in carbohydrate in sprouting soybeans. *Cromlie* and *co-workers* [26, 27, 28] working on germination of *Citrullus vulgaris* also pointed out that variation of sugars, starch and residual dry weight in different parts of the plants occurred on account of fat metabolism.
A slight increase in total sugar from 1st day onwards may be because of hydrolysis of starch by means of either phosphorylase activity or because of presence of a little amylase activity or moisture content of the seeds or by all the three. The decrease in starch content after attaining maximum value might be due to amylase activity, a starch splitting enzyme, as it has attained maximum value on 4th day in some cases and on 6th day in the remaining cases of our study. The maximum value of amylose observed from 4th day (Ur, GA, AA, DW, Con, MT) and thereafter (MH – 5th day; PC, SP, SA – 6th day) in varied cases during germination is a direct result of the fact that starch decreases because of its splitting into amylose and the rate of its splitting is higher than its formation from soluble sugars *via* phosphorylase activity or because of photosynthesis. *Philip Nordin* [29], while studying the changes in sugar concentrations during germination of sorghum grain, found that free sugars are working as energy sources in germination until amylose is produced by the hydrolysis of starch.
In the present study, the period of obtaining maximum value in case of total and reducing sugars appeared to be the same in varied treatments. Amongst fertilizer treatments amount of total and reducing sugars had obtained maximum value in the following order:

SP > PC > Ur.

Thus, it is suggested that phosphetic fertilizer has a remarkable influence on the production of sugars compared with the potash and the nitrogenous fertilizers. Further, in case of control seeds amount of total and reducing sugars was found to be higher than with the urea treatment and it was found to be lower in the DW treatment as the maxima indicate that soaking treatments must have an adverse effect on the embryo, over and above its merits such as ease of giving treatment, requirements of low conc. of the chemicals *etc.*, by creating dormancy in the active centres while drying the treated seeds to attain constant value before sowing them in a sand bed (medium) for germination. The higher value of total and reducing sugars in control seeds, the seeds which had not passed through pre-soaking treatment, compared with the urea treatment might be due to the very slow effect of nitrogenous fertilizer on the active centres *viz.* mitochondria, where enzymic activity resides and which affects the metabolic processes, in bringing them to a normal state as that of control seeds. The effect of SP and PC on the amount of total and reducing sugars also depends upon how they are activating the mitochondrial functions.
In case of growth regulator treatments following orders were marked with respect to total and reducing sugars:

AA > GA > MH > SA (Total sugars);
GA ≃ MH > AA > SA (Reducing Sugars).

In the above orders except AA, the trend with respect to amount of total and reducing sugars at the maxima is almost the same. The good amount of reducing sugar in GA compared to AA treatment may be because of relatively more accumulation of reducing sugars, produced from non-reducing sugars, in GA treatment than in the AA. Further, in AA treatment there is a large amount of amylose and the higher value of starch compared to GA seeds at the maxima for the same period of germination (Figs. 8 and 6) which leads us to believe that reducing sugars in AA treatment must have transformed to amylose through proper enzymes. Varied effects of chemicals on the contents of total and reducing sugars during germination and especially at the maxima are basically depending on how much mitochondria are affected by the treatment and thereby the enzymic activities and yield of the varied metabolites, because in the early stages one cannot expect major role of photosynthesis.

During the work ascorbic acid content was found to reach maximum on the 6th day of germination in all the cases except MT-treated seeds where maximum value occurred on the 2nd day of germination [29]. Ascorbic acid oxidase (AAO) was found regularly in an increasing order during germination, but the rate of increase was more pronounced in MT-treated seeds and was next in the value in AA-treated seeds amongst the cases studied. Further, it is also reported in literature that a part of the carbohydrate is utilized [19] in the formation of ascorbic acid. *Franke* [30] has mentioned that the formation of AA is associated with the process of degradation rather than synthesis. A decrease of total and reducing sugars from 4th day onwards in all the cases except MH and MT-treated seeds may be partly due to conversion of soluble sugars into ascorbic acid. In MT-treated seeds, as per expectation, AA should have maximum value after the 6th day of germination but experimental results had shown maximum value of AA on the 2nd day of germination, which may be due to high AAO activity from 2nd day onwards compared to other treatments [22]. Similarly, in MH-treated seeds, looking to the maximum value of total and reducing sugars on the 6th day of germination and if production of AA is mainly because of conversion of soluble sugars one expects maximum value of AA after 6th day of germination but experimentally AA was also found to reach maximum on the 6th day of germination [29] which may be due to minimum AAO content amongst all the cases studied and its rate of increase being also minimum throughout the period of germination might have helped in attaining the maximum value on the 6th day and not thereafter. Hence, it can be concluded that carbohydrate fragments are converted to AA in all the cases studied but the rate of conversion to AA in varied cases is different because pre-soaking treatments have their own effect on mitochondria and thereby the enzymic activities which affect degradation and synthesis of varied metabolities.

Above all, from the present results it is apparent that in MT-treatment amounts of total and reducing sugars were high compared to other treatments at the maxima, and the attainment of maximum values was late during the germination periods with low contents of amylose and starch. Further, the vegetative growth, the free amino acids viz. arginine and serine; the amino acids of lower peptide *viz.* cystine, alanine, glutamic acid, serine, tyrosine; and ascorbic acid were found higher [22] compared to other treatments and especially with respect to ingredients of mix-treatment, *viz.* AA and PC separately. Thus, it seems that the nutritive metabolites are much higher in MT treated seeds compared to other cases which leads us to suggest the use of suitable optimum conc. of growth regulator and fertilizer in pre-soaking treatment to have vegetables of high nutritive value and probably the yield, if one proceeds ahead, to a maturity stage.

Summary

The effect of pre-soaking treatments of optimum concentration of fertilizers *viz.* Urea (150 mg/100 ml), potassium chloride (90 mg/100 ml), sodium phosphate (100 mg/100 ml), and growth regulators *viz.* gibberellic acid (30 mg/100 ml), ascorbic acid (90 mg/100 ml), maleic hydrozide (50 mg/100 ml), sulphanilamide (50 mg/100 ml), each one separately, on the carbohydrate contents *viz.* total sugar, reducing sugars, starch and amylose of *Cucurbita pepo* (pumpkin) seeds of local variety during germination periods upto 12 days were studied. The carbohydrate contents of the seeds after mix treatment (MT) of optimum concentrations of fertilizer *viz.* potassium chloride (PC) and of growth regulator *viz.* ascorbic acid (AA) were also studied for the same periods. From the study of the carbohydrate contents of distilled water treated and control seeds effect of individual chemical and of mixture (*viz.* PC + AA) was studied. Variations in the contents of carbohydrate during growth periods are explained on the basis of mutual effects of metabolites and of certain related enzymes over and above the effect of method of pre-soaking treatment and of chemicals on the mitochondrial function. It is also reported that the vegetative growth and the nutritive value of MT are higher than in the other cases studied.

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Changes in Properties of Some Maize Cultivars Associated with Artificial Drying at Elevated Temperatures

Part I. Wet Milling Properties

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The effect of artificial drying at elevated temperature on the wet milling properties of a number of different maize cultivars, harvested at very high (> 30%) moisture levels, was studied. The degree of heat damage, assessed by the drop in starch yield on wet milling, varied appreciably according to cultivar, and was considerable for most of the cultivars when dried at 100 °C but relatively small for cultivars dried at lower temperatures and for cultivars dried at 100 °C from lower (< 25%) initial moisture levels. The protein content of the starch fraction, both before and after purification, did not vary greatly according to cultivar or to the drying conditions used.

Änderungen der Eigenschaften einiger Maissorten unter dem Einfluß künstlicher Trocknung bei erhöhten Temperaturen. 1. Teil. Naßvermahlungseigenschaften. Die Wirkung künstlicher Trocknung bei einer Anzahl verschiedener, mit sehr hohen Feuchtigkeitsgehalten (> 30%) geernteter Maissorten auf die Naßvermahlungseigenschaften wurde untersucht. Das Ausmaß der Hitzeschädigung, begleitet von einer Verminderung der Ausbeute bei der Naßvermahlung, schwankte stark und war bei den meisten Sorten beträchtlich, wenn diese bei 100 °C getrocknet wurden. Die Hitzeschädigung war jedoch relativ gering bei niedrigeren Trocknungstemperaturen und bei Sorten, die bei 100 °C, aber niedrigeren Anfangsfeuchtigkeiten (< 25%) getrocknet wurden. Der Proteingehalt der Stärkefraktion, sowohl vor als auch nach der Reinigung, schwankte weder zwischen den einzelnen Sorten noch mit den angewendeten Trocknungsbedingungen beträchtlich.

1 Introduction

Maize is frequently harvested at moisture levels much greater than the maximum acceptable for safe storage (*ca.* 14%) and, for this reason, it may be subjected to some form of artificial drying. Elevated temperatures may be used in order to accelerate the drying process.
A number of undesirable changes in properties have, however, been reported in the case of maize dried at excessively high temperatures. Grain of this type may be unsatisfactory for wet milling [1] and dry milling [2] and may also have a lower nutritional value than sound grain [3]. Milling quality may also be influenced by the method of drying used [4].
Maize which has been dried at temperatures above about 70 °C may give poor starch/protein separation [1] and reduced prime starch yields on wet milling [1, 5, 6]. Other factors, such as period of drying, relative humidity and air flow rate during drying may also influence starch yield. According to *Watson* and Hirata [1], starch yields for grain dried at temperatures of up to 82 °C are affected little by initial moisture levels of up to 32%. *Holaday* [5], however, obtained a lower starch yield from grain dried at 71 °C from 33% initial moisture than from grain dried at the same temperature from 29% initial moisture.
The susceptibility of different cultivars to damage, with regard to starch yield and starch purity, under standardised drying conditions, was not studied, however. For this reason, an investigation was made of changes in the wet-milling properties of a number of different maize cultivars on drying at elevated temperature under specified conditions and of the changes in other, more readily measurable, properties which may be associated with them and which may be useful for the detection of this type of damage.

2 Experimental

2.1 Maize Cultivars

A total of 10 cultivars, including three high-lysine cultivars, from the 1978 South African crop were obtained from the Summer Grain Research Centre, Potchefstroom. These are listed in Table 1. In order to investigate the effect of drying from very high initial moisture levels, these samples were

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