|  |
| --- |
|  |
| ***Research Document on PGRs to Enhance Sucrose Accumulation per Unit Area*** |
|  |
|  |
|  |
|  |

|  |
| --- |
|  |

***Research Document on PGRs to Enhance Sucrose Accumulation per Unit Area***

Plant Growth Regulators (PGRs) are chemicals that influence the growth and development of plants by affecting various physiological processes, including photosynthesis, nutrient translocation, and sucrose accumulation. In sugar-producing crops, PGRs can play a significant role in improving sucrose content by regulating the plant's hormonal balance and metabolic pathways.

**Detailed Explanation of PGRs to Enhance Sucrose Accumulation:**

**1. Ethylene and its Role in Ripening and Sucrose Accumulation**

* **Function of Ethylene**: Ethylene is a naturally occurring plant hormone involved in the ripening process and the regulation of sugar metabolism. In sugarcane and other sugar-producing crops, ethylene can enhance the movement of sucrose from leaves to storage tissues (e.g., stems or roots).
* **Application**: Ethylene or ethylene-releasing compounds like ***ethephon*** are commonly used to induce ripening in sugarcane. Ethephon breaks down into ethylene when absorbed by the plant. This increase in ethylene levels accelerates the metabolic process, leading to faster sugar accumulation and better ripening synchronization across the crop.
* **Effect on Sucrose Levels**: Ethylene can stimulate the activity of enzymes involved in sucrose synthesis, such as *sucrose-phosphate synthase*, enhancing the conversion of glucose and fructose into sucrose. By modulating sugar metabolism and promoting the degradation of starch into soluble sugars, ethylene application leads to a higher sucrose concentration in the harvestable parts.

**2. Gibberellins Inhibitors and Vegetative Growth Control**

* **Role of Gibberellins**: Gibberellins (GA) are growth hormones that promote cell elongation, seed germination, and vegetative growth. While gibberellins are important for overall plant development, excessive GA activity can cause the plant to divert resources toward vegetative growth, reducing the amount of energy available for sucrose accumulation.
* **Application of Gibberellin Inhibitors**: Inhibitors of gibberellins, such as *paclobutrazol* and *trinexapac-ethyl*, are used to limit the excessive elongation of stems and leaves, which can otherwise reduce the efficiency of sugar production. By controlling the growth of the plant, more energy is directed towards sucrose accumulation in the storage tissues rather than excessive foliage growth.
* **Impact on Sugar Content**: By inhibiting gibberellins, the plant allocates more resources to sugar storage, resulting in increased sucrose concentration in the stems or roots. This practice is particularly useful in crops like sugarcane, where controlling stem growth at certain stages of development can enhance the final sucrose yield.

**3. Cytokinins and Sucrose Mobilisation**

* **Function of Cytokinins**: Cytokinins are hormones that promote cell division and growth. They also play a key role in nutrient translocation, particularly in mobilising sugars from source tissues (leaves) to sink tissues (roots or stems).
* **Application of Cytokinins**: Exogenous application of cytokinins can enhance the mobilisation of photosynthetic products, such as sucrose, from the leaves to the storage organs (e.g., sugarcane stems or sugar beet roots). This ensures that more of the sugars produced during photosynthesis are stored in the harvestable parts of the plant.
* **Effect on Sugar Accumulation**: Cytokinins help in maintaining a longer duration of active growth in the leaves, improving photosynthetic activity and increasing sugar production. They also enhance the sink strength of the storage tissues, attracting more sucrose for deposition.

**4. Abscisic Acid (ABA) and Stress-Induced Sucrose Accumulation**

* **Role of Abscisic Acid**: ABA is a plant hormone primarily involved in stress responses, including drought and high salinity. It can also affect sugar metabolism by regulating enzyme activities that influence sucrose breakdown and synthesis.
* **Use in Sugar Production**: Under controlled conditions, the application of ABA can induce mild stress responses in plants, leading to enhanced sugar accumulation. For example, drought stress mediated by ABA can increase sugar content as the plant concentrates resources for survival.
* **Impact on Sucrose Levels**: ABA helps the plant to respond to stress by activating sucrose synthesis pathways, thereby increasing the concentration of sugars stored in the crop. While too much stress can damage the plant, controlled ABA-induced stress can optimise sucrose accumulation in some crops.

**5. Auxins and Their Limited Use in Sugar Production**

* **Role of Auxins**: Auxins primarily regulate cell elongation and growth. While important for plant development, auxins do not directly contribute to sugar accumulation. In fact, high levels of auxins can inhibit sucrose storage by promoting vegetative growth over sugar storage.
* **Regulation in Sugar Production**: Auxins are typically not applied for the purpose of increasing sucrose accumulation, and their application is often avoided during the ripening phase. Instead, inhibitors of auxin activity or reducing auxin levels naturally through environmental controls may promote better sugar storage.

**Best Practices for Using PGRs in Sugar Crops:**

* **Timing of Application**: PGRs must be applied at the correct developmental stage of the crop. For example, ethylene-based PGRs should be applied during the ripening phase, while gibberellin inhibitors are best used earlier to control excessive vegetative growth.
* **Concentration and Dosage**: The dosage of PGRs is crucial. Over-application of growth regulators can have detrimental effects, such as inhibiting growth too much or causing premature ripening.
* **Environmental Considerations**: PGRs should be used in conjunction with good agricultural practices like proper irrigation and nutrient management to ensure the best results in sugar accumulation.

By using PGRs strategically, farmers can manipulate the plant’s growth and sugar metabolism to increase the sucrose content, improving overall yield and profitability of the crop.

**Ethephon** is an ethylene-releasing plant growth regulator used in sugarcane to accelerate ripening and enhance sucrose accumulation. Its application can influence the sugar content and the overall yield, including the increase in **Brix**—a measure of sugar concentration in juice.

**1. Rate of Ethephon Application**

The rate of ethephon application in sugarcane depends on several factors, including the growth stage, environmental conditions, and the variety of sugarcane being cultivated. Typical application rates for ethephon in sugarcane production are:

* **Standard Rate**: Between **250 to 500 grams of active ingredient per hectare (g a.i./ha)**.
* **Concentration**: Ethephon is often applied as a foliar spray at concentrations ranging from **200 to 300 ppm (parts per million)**.
* **Timing**: Ethephon should generally be applied **2 to 3 weeks before harvest** to ensure that the sugarcane plant has enough time to respond to the ethylene produced. Applying it too close to harvest may not allow sufficient time for sucrose accumulation.

The exact rate can vary depending on the cultivar and environmental conditions, but staying within these ranges helps avoid excessive senescence or stress to the plant, which could reduce ratoon vigor or even lower overall yield.

**2. Effect on Sugar Production**

Ethephon promotes sucrose accumulation in sugarcane by enhancing metabolic processes such as:

* **Increased Sucrose Content**: Ethephon increases the activity of sucrose-synthesizing enzymes like *sucrose phosphate synthase*, which enhances the conversion of simpler sugars (glucose and fructose) into sucrose.
* **Reduction in Growth Processes**: By inducing ripening, ethephon inhibits further vegetative growth and directs the plant’s energy towards storing sugars in the stem, which increases the total sugar content available at harvest.

Studies have shown that ethephon application can lead to an increase in sugar content of the crop by approximately **10 to 15%**. This translates into a higher yield of recoverable sugar per tonne of sugarcane.

**3. Impact on Brix Readings**

**Brix** is a key indicator of sugar concentration, measured as the percentage of soluble solids (mainly sucrose) in the cane juice. The higher the Brix value, the greater the sugar content in the juice.

After applying ethephon, the following changes can be observed in Brix values:

* **Pre-Ethephon Application Brix**: Before applying ethephon, Brix values in sugarcane juice typically range between **16-18** in normal ripening conditions.
* **Post-Ethephon Application Brix**: After the application of ethephon, Brix values can increase by **1 to 3 degrees**, depending on the rate of application and environmental factors. For example, if the Brix value was originally 18, it could rise to **19-21 Brix** following ethephon treatment. This increase represents higher sucrose accumulation in the juice, which is a direct result of the plant's ripening response to ethylene.

**4. What to Expect from Samples**

When samples are taken after the application of ethephon, you would typically observe:

* **Increase in Juice Sucrose Concentration**: The percentage of sucrose in the juice extracted from sugarcane stems will be higher, corresponding to an increase in the Brix level. A rise of 1 to 3 Brix points is often observed.
* **Higher Total Soluble Solids**: Besides sucrose, other soluble solids in the cane juice, such as glucose and fructose, will contribute to the Brix value. However, the proportion of sucrose to total soluble solids will increase, improving the overall quality of the cane.

**5. Economic Impact**

The increase in Brix values, and thus sucrose concentration, translates to a higher yield of **recoverable sugar per tonne of cane**. For example:

* If the average sugar yield without ethephon is **12-14 tonnes of sugar per hectare**, after applying ethephon, this could increase to **13-16 tonnes** due to the enhanced sucrose accumulation.
* A **10-15% increase** in sucrose translates into higher profits for sugar producers, especially in areas where the market value of sugar is tied directly to its sucrose content.

**Summary:**

* **Rate of Application**: 250-500 g a.i./ha (200-300 ppm) applied 2-3 weeks before harvest.
* **Increase in Sugar Production**: Around 10-15% higher sucrose accumulation.
* **Brix Increase**: Expect a rise of 1-3 Brix points, translating to higher sugar concentration in the juice.
* **Overall Impact**: Enhanced sugar yield per hectare, improving both productivity and profitability.

By carefully managing the rate and timing of ethephon application, sugarcane growers can significantly improve sugar yields without negatively affecting the plant's health or ratooning ability.

***Ethephon as PGRs for Tillering and Sucrose Accumulation***

**Ethephon** is sometimes used early in the growth cycle to promote tillering (branching) and increase the number of cane stalks per unit area. This is because, at early growth stages, **ethylene** (which ethephon releases) can stimulate tillering by promoting lateral bud growth. However, when applied later in the crop cycle, **ethephon acts as a ripening agent**, accelerating the maturation of sugarcane and enhancing sugar accumulation. Let’s explore how ethephon works for both tillering and ripening, and how its mode of action differs from herbicides like **Touchdown** or **Roundup**.

**1. How Ethephon Works as a Ripening Agent**

Ethephon’s effect on ripening comes from its ability to release **ethylene gas** when it is absorbed by the plant. Ethylene is a natural plant hormone that controls many developmental processes, including fruit ripening, senescence, and sugar accumulation. In sugarcane, applying ethephon during the **late growth stage** (2-3 weeks before harvest) has the following effects:

* **Inhibition of Vegetative Growth**: As the sugarcane plant reaches the late stages of development, applying ethephon suppresses vegetative growth, which means the plant stops producing new leaves or stems. This redirection of energy is critical because it forces the plant to focus on ripening and sugar accumulation rather than further growth.
* **Acceleration of Senescence**: Ethylene promotes senescence (the natural aging process), which leads to the breakdown of chlorophyll in leaves and the mobilization of sugars from the leaves and stems into the cane stalks. This is important for sugarcane, as senescence signals the plant to redirect stored sugars to the stalks, where sucrose is stored.
* **Increased Sucrose Accumulation**: As vegetative growth slows and senescence progresses, the plant redirects photosynthetic products, especially sugars, into the cane stalks. Ethephon stimulates the enzymes that synthesize sucrose (such as *sucrose phosphate synthase*), leading to higher sucrose concentrations in the cane juice.

The result is **faster ripening** and higher **Brix** levels (a measure of sugar concentration) in the cane juice, making the cane ready for harvest earlier with increased sucrose content.

**2. How Ethephon Affects Early Growth (Tillering)**

In the **early growth stage**, ethephon can stimulate the formation of more tillers (secondary shoots from the base of the plant), increasing the overall number of stalks per unit area. The application of ethephon early on helps the plant develop a more robust structure with more stalks, which eventually leads to higher cane yield.

* **Tillering Mechanism**: Ethylene promotes the growth of lateral buds by reducing the dominance of the main shoot (apical dominance). This allows the plant to produce more shoots or tillers, enhancing the plant's biomass and density.
* **Resulting Effect**: Early applications of ethephon result in an increase in cane stalks per unit area, improving overall productivity.

**3. Ethephon vs. Touchdown/Roundup (Glyphosate-based Herbicides)**

**Touchdown** and **Roundup** are **glyphosate-based herbicides** that work by inhibiting a key enzyme in plants, **5-enolpyruvylshikimate-3-phosphate synthase (EPSP synthase)**, which is critical for the production of essential amino acids needed for plant growth. These herbicides are typically used for **weed control**, but when applied at sub-lethal doses, glyphosate can also be used as a **ripener** in sugarcane. Here’s how glyphosate compares to ethephon for ripening:

* **Glyphosate as a Ripener**: Glyphosate inhibits protein synthesis and blocks plant growth, which forces the plant to stop growing and directs resources (including sugars) to the cane stalk. Glyphosate can also inhibit certain enzymes that break down sucrose, allowing more sugar to accumulate in the stalk. However, glyphosate is slower-acting compared to ethephon.
* **Ethephon vs. Glyphosate (Touchdown/Roundup)**:
  + **Speed of Action**: Ethephon acts faster than glyphosate for ripening because ethylene is a natural ripening hormone that quickly accelerates sugar accumulation and senescence. Glyphosate takes longer to affect plant metabolism since it works by inhibiting amino acid synthesis.
  + **Mode of Action**: Ethephon works by promoting ethylene release, which is a natural part of plant development, while glyphosate interferes with fundamental metabolic pathways. This difference in action means that glyphosate ripens the plant more gradually, whereas ethephon provides a quicker response.
  + **Selective Effect**: Ethephon specifically targets ripening processes without severely harming the plant, making it ideal for rapid sugar accumulation. Glyphosate, when applied at sub-lethal doses, can suppress growth but may have more widespread effects on the plant, potentially stressing it more severely.

**4. Application and Effects on Sugarcane Ripening**

When using **Ethephon** for ripening:

* **Timing**: Ethephon should be applied **2 to 3 weeks before harvest** to enhance ripening and maximize sugar accumulation. Application at this stage ensures that the plant has stopped growing vegetatively and directs resources towards sugar storage.
* **Rate of Application**: The typical rate is **250-500 g a.i./ha** (active ingredient per hectare), though this can vary based on local conditions and cane varieties.

When using **Glyphosate (Touchdown or Roundup)** as a ripener:

* **Timing**: Glyphosate should be applied **4 to 6 weeks before harvest**, as it takes longer to induce ripening compared to ethephon.
* **Rate of Application**: Glyphosate is used at much lower doses for ripening than for weed control, usually **0.5 to 1 kg a.i./ha**.

**5. Practical Considerations**

* **Faster Ripening**: Ethephon is generally preferred when a **quicker ripening response** is needed, as it accelerates the ripening process more effectively within a shorter timeframe.
* **Environmental Considerations**: Ethephon is safer for sugarcane crops in terms of selectivity, as it targets the natural ethylene pathways for ripening. Glyphosate, if applied incorrectly, could stress or damage the crop, especially if the dosage is too high.

**Conclusion:**

* **Ethephon** can be used to ripen sugarcane by accelerating the accumulation of sucrose and stopping vegetative growth, making it ideal for fast ripening before harvest. It works through ethylene production, stimulating the plant's natural ripening processes.
* **Touchdown or Roundup (Glyphosate)**, when used at low doses, also induces ripening, but it works by inhibiting amino acid synthesis, causing the plant to stop growing and accumulate sugars. Glyphosate acts slower and is less precise compared to ethephon in terms of speed and target mechanisms.

In summary, while ethephon promotes tillering early in the crop cycle, it acts as an efficient ripening agent when applied later, outperforming glyphosate in speed and precision for sugarcane ripening.