Effects of ethephon, salicylic acid and cidef-4 on the yield and quality of guinea grass seed

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Abstract

The effect of applying plant growth regulators on seed yield and quality of guinea grass (Panicum maximum) cv. Tanzania was studied in one crop on a sandy clay in Mexico. The treatments consisted of 3 growth regulators [ethephon, salicylic acid and a steroidal phytohormone (cidef-4)], 2 stages of application (before seed head emergence and at the beginning of anthesis) and 4 application concentrations [0, 600, 1200 and 1800 mg/kg active ingredient (a.i.) for ethephon; 0, 10−5, 10−4 and 10−3 M for salicylic acid; and 0, 2, 4 and 6 mg/kg a.i. for cidef-4]. The growth regulators were applied as a spray in water at 850 L/ha. Pure seed yield varied between the growth regulators evaluated (P<0.05), and the greatest yield (179 kg/ha) was obtained using cidef-4. Ethephon greatly reduced seed yields at the highest 2 rates when applied early, mainly through reducing number of heads emerging. Salicylic acid had a beneficial effect on seed yield at the highest application rate, irrespective of when applied. Cidef-4 greatly increased seed yield, irrespective of when applied, with the effect tending to increase with application rate over the full range. It acted primarily through an increase in head density and to a lesser extent head size. Seed quality (1000-seed weight, seed purity and germination %) was not significantly affected by any of the treatments applied.

Introduction

Seed production of tropical pasture grasses such as guinea grass (Panicum maximum) presents serious difficulties associated with poor synchrony of flowering and rapid abscission of ripe seeds, causing low yield and poor quality of seed (Boonman 1978; Oliveira and Humphreys 1986). These problems may be partially overcome by using different agronomic practices and genetic improvement, which may result in a reduction of forage yield (Hebblethwaite et al. 1980). The main management strategy to improve seed production in these species is to identify specific stages of plant development where yield can be maximised. Many studies on management of tropical grasses have revealed an increase in seed yield by imposing a final closing cut at an appropriate time, applying nitrogen fertilisers and manipulating tillering density, or by combining these practices (Boonman 1978). In a previous study, where nitrogen fertilisation and harvesting time were evaluated in guinea grass cv. Tanzania, yield and seed quality increased with application of 100 and 150 kg/ha N (Joaquín et al. 2001a; 2001b). The highest seed yield was observed when guinea grass was harvested at 18–22 days after anthesis, when moisture content and percentage of spikelet abscission were 45–50% and 33–53%, respectively. However, seed yield in guinea grass might be further increased by the application of growth regulators, which have a profound effect on increasing synchrony of flowering, homogeneity of seed ripening, seed yield and quality in several species of plants (Nickell 1979; Pérez and Reyes 1990). Information is needed regarding the effect of growth regulators on seed production of tropical pasture grasses. This study aimed to evaluate the effect of different rates of ethephon, salicylic acid and a commercial steroidal phytohormone (cidef-4), applied either before seed head emergence or at the beginning of anthesis, on seed yield and quality of guinea grass cv. Tanzania.
Materials and methods

Site, experimental design and pasture management

The study was conducted during 2000 at Ex-Hacienda de Ixtapan, Tejupilco, State of México (18° 54' N, 100° 08' W; 1320 masl). The site has a warm, subhumid climate, with a summer rainfall regimen. Total rainfall and mean temperature during the study were 1070 mm and 19.6°C, respectively. The soil texture was sandy clay, with an average pH of 6.4, 3.5% organic matter and 35, 4.6 and 212 mg/kg available N, P and K, respectively.

The guinea grass sward was sown in June 1998, at a spacing of 80 cm between rows with 70 cm between plants within rows. It was grazed by cattle until treatments were imposed on September 4, 2000. On September 5, the area was fertilised with 150 kg/ha N, 22 kg/ha P and 44 kg/ha K, using urea (46% N), triple calcium superphosphate (21% P) and potassium chloride (53% K). Weeds were controlled manually before seed head emergence. The treatments were combinations of 3 growth regulators [ethephon, salicylic acid and a commercial steroidal phytohormone (cidef-4)], 4 application concentrations and 2 application dates (before seed head emergence and at the beginning of anthesis). Application concentrations were: ethephon (0, 600, 1200 and 1800 mg/kg active ingredient); salicylic acid (0, 10^-5, 10^-4 and 10^-3 M); and cidef-4 (0, 2, 4 and 6 mg/kg active ingredient). All growth regulators were dissolved in 1 L of water and finely sprayed over entire plants during the evening (after 17:00 h) at 850 L/ha. To achieve better penetration, 1 mL/L of a non-ionic surfactant (polieter-polimetilsiloxano) was added to the spray solution.

Plot size was 3 m × 7 m. Treatments were arranged as a split-split plot experiment with 3 replicates in a randomised complete block design with growth regulators as the main plot, application date as the sub-plot and application rates as the sub-sub-plot. The application before seed head emergence was carried out on October 4, 2000 and that at the beginning of anthesis on October 16, when 10% of the total seed heads per plant were in anthesis. The seed head emergence stage has been defined as the time at which 5 inflorescences per m² have emerged (Boonman 1971). This occurred on October 8, 2000. Anthesis was defined as the time when exserted anthers could be found on at least one spikelet of at least half of the inflorescences. This occurred on October 22.

Seed harvesting

Treatments were harvested 20 days after anthesis when the seeds had 45–46% moisture content (Joaquín et al. 2001a), according to the technique for tropical forage grasses (Ferguson 1978), which consists of cutting all inflorescences and then subjecting them to a natural sweating process. To simulate sweating, the harvested heads were placed in cotton bags, which themselves were grouped and covered with the remaining vegetative material for 4 days. Seed heads were threshed manually. The seed obtained was cleaned and air-dried to 10% moisture, which was determined according to the Rules of ISTA (1993). Samples of seed from each plot were weighed and stored in paper bags under laboratory conditions for 6 months.

Seed processing and seed quality testing

Pure seed yield, number of seed heads/m², seeds produced/seed head, harvested seeds/seed head, 1000-seed weight, physical seed purity and seed germination were recorded. Pure seed yield was measured as the product of gross seed yield and purity. The number of seed heads/m² was determined on 3 plants previously selected at random in each plot. Seed numbers produced and harvested seeds/seed head were determined on 10 ripe inflorescences, taken randomly from the 3 plants previously selected. Harvested seeds/seed head were determined by counting the number of spikelets present in each of the 10 ripe inflorescences, while the number of seeds produced/seed head was determined by adding the number of abscission calluses to the number of spikelets present. Physical seed purity and 1000-seed weight were determined according to the Rules of ISTA (1993). Seed germination was determined 6 months after harvest. Samples of 100 pure seeds per treatment were taken from each of the 3 replicates for germination tests. These were placed on filter paper in petri dishes and incubated in a germination cabinet at 30 ± 1°C for
Growth regulators and seed production of *Panicum maximum*

28 days. Percentage germination was estimated using the number of normal seedlings and the number of seeds tested (ISTA 1993).

**Statistical analysis**

Data were statistically analysed by analysis of variance in the General Linear Models Procedures of SAS. Differences among treatments were considered to be significant at P<0.05. Means were compared using Tukey’s method and least significant difference test (SAS Institute Inc. 1988).

**Results**

Table 1 shows the mean values for all parameters measured for all treatments. Table 2 shows the growth regulator treatment values as a percentage of the control, calculating the control value as a composite mean for all zero treatments.

**Ethephon effects**

The highest rate of ethephon (1800 mg/kg), when applied before seed head emergence, significantly decreased pure seed yield to 8%, number of seed heads/m² to 15%, seeds produced/seed head to 45%, and harvested seeds/seed head to 37%, compared with the overall control mean considered as 100% (Table 2). On the other hand, for characters related to seed quality, such as 1000-seed weight, seed purity, and seed germination, the response was less drastic (91, 82 and 85%, respectively). When ethephon was applied later at the beginning of anthesis, the effect, irrespective of rate, was small for nearly all seed characteristics (Table 1; P>0.05). The only exception was the 21% decrease in harvested seeds/seed head (79% of control) at the highest application rate (Table 2).

**Salicylic acid effects**

When salicylic acid was applied before seed head emergence at the highest rate, it increased pure seed yield to 164%, number of seed heads/m² to 144% and seeds produced/seed head to 117% of the control values (Table 2). However, when application was delayed until the beginning of anthesis, also at the highest rate, it increased pure seed yield to 153% and number of seed heads/m² to 133% of those for the control. The effect at

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**Table 1.** Mean values for pure seed yield and its components, and physical and physiological seed quality of *Panicum maximum* cv. Tanzania in response to application of 3 growth regulators at 2 stages of plant maturity.

<table>
<thead>
<tr>
<th>Parameter1</th>
<th>PSY</th>
<th>NH</th>
<th>SPH</th>
<th>HSH</th>
<th>TSW</th>
<th>SP</th>
<th>SG</th>
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<tbody>
<tr>
<td>Timing2 Treatment3</td>
<td>S1</td>
<td>S2</td>
<td>S1</td>
<td>S2</td>
<td>S1</td>
<td>S2</td>
<td>S1</td>
</tr>
<tr>
<td>Control4</td>
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<td>39</td>
<td>846</td>
<td>599</td>
<td>1.29</td>
<td>85</td>
<td>80</td>
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<tr>
<td>E1</td>
<td>87</td>
<td>99</td>
<td>32</td>
<td>57</td>
<td>715</td>
<td>795</td>
<td>584</td>
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<tr>
<td>E2</td>
<td>18</td>
<td>79</td>
<td>18</td>
<td>45</td>
<td>570</td>
<td>793</td>
<td>367</td>
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<tr>
<td>E3</td>
<td>6</td>
<td>96</td>
<td>6</td>
<td>52</td>
<td>380</td>
<td>823</td>
<td>221</td>
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<tr>
<td>LSD (P&lt;0.05)5</td>
<td>37.3</td>
<td>18.6</td>
<td>148.9</td>
<td>146.2</td>
<td>0.037</td>
<td>6.6</td>
<td>4.5</td>
</tr>
<tr>
<td>S1</td>
<td>60</td>
<td>70</td>
<td>54</td>
<td>57</td>
<td>854</td>
<td>820</td>
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<td>73</td>
<td>36</td>
<td>39</td>
<td>683</td>
<td>701</td>
<td>409</td>
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<tr>
<td>S3</td>
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<td>116</td>
<td>56</td>
<td>52</td>
<td>991</td>
<td>726</td>
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<tr>
<td>LSD (P&lt;0.05)5</td>
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<td>224.0</td>
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<td>0.028</td>
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<td>C1</td>
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<td>110</td>
<td>70</td>
<td>58</td>
<td>1144</td>
<td>904</td>
<td>745</td>
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<tr>
<td>C2</td>
<td>126</td>
<td>158</td>
<td>46</td>
<td>68</td>
<td>905</td>
<td>1169</td>
<td>650</td>
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<tr>
<td>C3</td>
<td>159</td>
<td>179</td>
<td>69</td>
<td>67</td>
<td>975</td>
<td>937</td>
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<tr>
<td>LSD (P&lt;0.05)5</td>
<td>44.2</td>
<td>13.5</td>
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<td>0.022</td>
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<td>LSD (P&lt;0.05)6</td>
<td>16.0</td>
<td>7.4</td>
<td>80.7</td>
<td>48.7</td>
<td>0.011</td>
<td>1.5</td>
<td>2.3</td>
</tr>
</tbody>
</table>

1 PSY = Pure seed yield; NH = Number of seed heads/m²; SPH = Seeds produced/seed head; HSH = Harvested seeds/seed head; TSW = 1000-seed weight; SP = Seed purity; SG = Seed germinated.
2 S1 = Before seed head emergence; S2 = At the beginning of anthesis.
3 E1 = Ethephon 600 mg/kg; E2 = Ethephon 1200 mg/kg; E3 = Ethephon 1800 mg/kg; S1 = Salicylic acid 10⁻⁵ M; S2 = Salicylic acid 10⁻⁴ M; S3 = Salicylic acid 10⁻³ M; C1 = Cidef-4 2 mg/kg; C2 = Cidef-4 4 mg/kg; and C3 = Cidef-4 6 mg/kg.
4 Control = Composite mean for all zero treatments (mean of 18 values).
5 LSD = Least significant difference among treatments.
6 LSD = Least significant difference: growth regulator × rate × stage of application interaction.
others rates was small and not significant for most seed characteristics. Attributes related to seed quality were not affected, the values all being similar to the control values (Tables 1 and 2).

**Cidef-4 effects**

Application of cidef-4 produced significant highly positive responses, irrespective of stage of application, especially in pure seed yield (209 and 236% of control), number of seed heads/m² (177 and 172% of control), and seeds produced/seed head (115 and 111% of control) for the early and later application times, respectively (Table 2). Variables related to seed quality were not significantly affected (P>0.05).

**Discussion**

**Growth regulators**

The varied responses in pure seed yield of guinea grass to application of growth regulators in this study are consistent with the results of other authors, who have found that exogenous application of growth regulators to plants may produce variable effects, depending on the chemical used, rate, stage of application and the plant species used. Similar results to those with cidef-4 were found in wheat, where the number of spikes, seeds/spike and 1000-seed weight were increased using steroidal compounds (Saíram 1994; Nuñez and Robaina 1998).

The substantial increase in the number of seeds produced and harvested seeds/seed head with the application of cidef-4 was probably due to a higher percentage seed set and increased amount of retained seed, in contrast to the tendency observed with both ethephon and salicylic acid. The fact that cidef-4 was effective at both ear emergence and anthesis suggests that the mechanism is effective through the releasing of already formed seed from some sort of inhibition (such as apical dominance), or by the stimulation of culm elongation, the positive effects being reflected in improved seed production but not seed quality.

Even though there are no reports on the use of salicylic acid to increase seed production in grasses, our results agree with those reported in wheat, where its application at rates between $10^{-8}$ and $10^{-2}$ M increased seed yield by up to 17% (García 1982; López 1989; Camacho 1991). Since the positive response in pure seed yield was observed only when salicylic acid was applied at the highest rate, higher application rates than $10^{-3}$ M should be investigated.

**Table 2.** Mean values for pure seed yield and its components, and physical and physiological seed quality of Panicum maximum cv. Tanzania in response to application of 3 growth regulators, expressed either as a percentage of the control or as the deviation from the control.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% of Control</th>
<th>Deviation from Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PSY</td>
<td>NH</td>
</tr>
<tr>
<td><strong>Timing</strong></td>
<td><strong>S1</strong></td>
<td><strong>S2</strong></td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>114</td>
<td>130</td>
</tr>
<tr>
<td>E2</td>
<td>24</td>
<td>104</td>
</tr>
<tr>
<td>E3</td>
<td>8</td>
<td>126</td>
</tr>
<tr>
<td>S1</td>
<td>79</td>
<td>92</td>
</tr>
<tr>
<td>S2</td>
<td>80</td>
<td>96</td>
</tr>
<tr>
<td>S3</td>
<td>164</td>
<td>153</td>
</tr>
<tr>
<td>C1</td>
<td>175</td>
<td>145</td>
</tr>
<tr>
<td>C2</td>
<td>166</td>
<td>208</td>
</tr>
<tr>
<td>C3</td>
<td>209</td>
<td>236</td>
</tr>
<tr>
<td>Control</td>
<td>76</td>
<td>39</td>
</tr>
</tbody>
</table>

1 PSY = Pure seed yield; NH = Number of seed heads/m²; SPH = Seeds produced/seed head; HSH = Harvested seeds/seed head; TSW = 1000-seed weight; SP = Seed purity; SG = Seed germinated.
2 S₁ = Before seed head emergence; S₂ = At the beginning of anthesis.
3 E₁ = Ethephon 600 mg/kg; E₂ = Ethephon 1200 mg/kg; E₃ = Ethephon 1800 mg/kg; S₁ = Salicylic acid $10^{-5}$ M; S₂ = Salicylic acid $10^{-4}$ M; S₃ = Salicylic acid $10^{-3}$ M; C₁ = Cidef-4 2 mg/kg; C₂ = Cidef-4 4 mg/kg; and C₃ = Cidef-4 6 mg/kg.
4 Control = Composite mean for all zero treatments (mean of 18 values).
Stage of application

When the ethephon was applied before seed head emergence, the result was a negative response in characters related to pure seed yield of guinea grass. However, when application was delayed until the beginning of anthesis, the effect, irrespective of rate, was positive for pure seed yield and number of seed heads/m². This indicates that applying ethephon before seed head emergence has a negative effect on emergence of seed heads with resultant reduction in seed yield. It has been reported that the total number of seed heads is the main yield component that directly relates to seed yield (Favoretto and Toledo 1975; Mejía et al. 1978; Loch 1980).

Cidef-4 greatly increased seed yield, irrespective of when applied, with the effect tending to increase with increase in application rate. It acted primarily through an increase in seed head density, with smaller impacts on number of seeds per seed head. These results are in agreement with those of authors such as Nuñez and Robaina (1998), who pointed out that steroidal compounds, applied to wheat plants during the flowering or grain-filling stage, increased seed yield, which was a function of a higher number of fertile spikelets, weight of heads and 1000-seed weight.

Application rate

Overall, growth regulators interacted significantly with stage and application rate (P<0.05) for pure seed yield and number of seed heads/m². Seed quality attributes such as 1000-seed weight, seed purity and germination % were not significantly affected by any of the treatments applied (Tables 1 and 2). We consider the main responses in pure seed yield were due to growth regulator effects on seed head emergence. Therefore, the focus of future research should be on the study of behaviour of the inflorescence from the time of its initiation to the time of emergence from the flag leaf.

Conclusions

Cidef-4 was the growth regulator that showed the most promising results by raising pure seed yield significantly through an increase in the density of seed heads regardless of the stage of application. Other studies are warranted to confirm these initial findings. Since salicylic acid increased pure seed yield at the highest rate, further testing with even higher rates seems warranted.

Application of ethephon before seed head emergence virtually arrested head emergence at high rates. Although application at the beginning of anthesis gave small responses in seed yield, further testing of this product seems unwarranted.

References

Nickell, L.G. (1979) Controlling biological behavior of plants with synthetic plant growth regulation chemicals. In:


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