Research Article

Effect of Different Levels of Naphthalene Acetic Acid at Various Phenological Stages of Hybrid Sorghum to Enhance Fodder Productivity

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Abstract | Goal of the study was to examine optimum level of Naphthalene Acetic Acid (NAA) as foliar application at various growth stages to increase the fodder productivity of hybrid sorghum. A field trial was carried out in RCBD having 3-replications with split-plot arrangement at Agriculture Research Farm, Faculty of Agriculture, Gomal University, Dera Ismail Khan, KP during 2017. Sorghum hybrid cv. "Jumbo+" was used as tested plant material. Four levels of NAA (40, 80, 120 and 160 ml ha^{-1}) were kept in main plots, while three crop growth stages (seedling, tillering and booting) of sorghum were kept in sub-plots. The crop was sown in month of July, while a seed rate of 25 kg ha^{-1} was used with manual drill. The crop received irrigation at interval of 15 days whilst fertilizer was applied @ 120-90-60 kg NPK ha^{-1}. Results revealed that levels of NAA affected significantly all parameters under study. Maximum number of leaves (16.70 $plant^{-1}$), leaf area (411.98 cm^2), chlorophyll contents (46.84 and 53.50 µg cm^{-2}) at 30 and 60 DAS and fodder yield (35550 kg ha^{-1}) were higher with L_4 (120 ml) followed by L_3 (80 ml). While L_5 (160 ml) and L_2 (40 ml ha^{-1} NAA) were statistically at par. Mean values indicated that NAA level of L_4 (120 ml ha^{-1}) had maximum fodder yield (35,550 kg ha^{-1}) as compared to control (13,024 kg ha^{-1}). The results indicated that interaction between 120 ml NAA ha^{-1}) at booting stage showed best results for productivity of fodder hybrid sorghum under agro-climatic condition of Dera Ismail Khan.

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Introduction

Sorghum crop is grown on area of 39.33 m ha in the world with production of 59.34 m metric ton (USDA, 2018). It is cultivated in dryer zones of Asia, Australia and America. It is 5th important cereal crop after wheat, rice, barley, and is source of food for more than 600 million people in different countries (Kumar *et al*., 2011). In Pakistan during year 2018, cultivated area of sorghum was 255 thousand hectares with the 154 thousand tons production (Anonymous, 2018). It is grown as a forage as well as sugar crop, biofuel crop and is mostly used as grain crop. In current situation, demand of grain and fodder sorghum is increasing day by day. In May-June and Oct-Nov, lack of fodder is quite common in Pakistan; it may be cultivated under irrigation and barani farming systems (Khan *et al*., 2013). Plant Growth Regulators (PGRs) for yield development, quality development and facilitation of harvesting together with genetic engineering represent supplementary techniques in agriculture for enhancing production of crop and usage of few resources. While, PGRs have been used in agriculture for crop protection as their adverse chemical effect has been comparatively less and limited to some specific culture (Djanaguiraman and Ramesh, 2013).

Applications of PGRs are useful not only to achieve the quality desired by the ethanol industry (Almodares *et al*., 2013) but the quality needed for other purposes as forage also. PGRs are compounds able to change the morphology and physiology of plants and can be applied at different times (Leite *et al*., 2011), depending on the grower purpose for crop. G3 (70 ppm NAA ha^{-1}) revealed the greater chlorophyll content. A quadratic association was originating b/w the chlorophyll and NAA level (Nagraj, 2009). Plant growth regulators are often used to control lodging by using chlormequat chloride (CCC), a gibberellin biosynthesis inhibitor (Rajala *et al*., 2002). ETH application also prohibited the lodging and was related with decrease in plant height, increase in stem wall width of 1st, 2nd and 3rd internodes (Tripathi *et al*., 2003). Current study was showed to examine effects of exogenous application of various levels of NAA on morphological traits of hybrid sorghum at 3-critical crop growth stages and to find the impact of NAA on green fodder production.

Materials and Methods

Site of experimentation

An experiment was undertaken at ARI D.I. Khan during 2017. Five samples were collected from the field from 0 to 30 cm depth. All the samples were individually analyzed for physic-chemical properties. The observations depicted that the soil was calcareous in nature while the location received low rainfall i.e. 180-250 mm with high summer temperature (35-40 °C) and a pH of more than 8.0. During the study year, total rainfall was recorded to be 215 mm.

Experimental procedure

Research experiment on effect of different levels of NAA at various phenological stages of hybrid sorghum to enhance fodder productivity was conducted at Agriculture Research Farm, Faculty of Agriculture, GU, Dera Ismail Khan, during 2017. This research trial was laid out in RCBD having three replicates with split-plot arrangement. Net plot size was 4×3m having 60 cm row to row managed at ridge sowing in each plot. Experiment included two factors i.e. five levels of NAA and three crop growth stages of sorghum. The field was prepared by applying one disc ploughing, one rotavator tillage and two cultivator ploughings with land leveling. Seed rate was 25 kg ha^{-1} for fodder. Sowing was done with hand drill. Sorghum hybrid "Jumbo+" was sown during the 3rd week of July. The fertilizer dose was applied 120-90-60 kg NPK ha^{-1}. The full dose of phosphorus, potassium and half level of nitrogen dose were used at sowing time, whereas remaining half level of N was used at tillering. Planofix (NAA) was applied by hand pump sprayer with 4.5% concentration as sodium salt in five levels at seedling, booting and tillering stage. NAA is a biodegradable and environment friendly chemical. Each concentration was made by dissolving each concentration (0, 40, 80, 120 and 160) dissolved in one litter of distilled water to make the required dose. These concentrations are made by reviewing past literature and finding. The experimental procedure and treatments details are given below;

Table: *Table showing weather conditions at experimental site (2017).*

Month	Temperature °C			R.F. (mm)
	Max	Min.	Avg.	
May	37.8	22.5	30.15	16.0
June	40.7	26.3	33.5	7.0
July	44.9	26.3	35.6	112.0
Aug.	40.0	21.1	30.55	40.0
Sept.	39.0	17.0	28.0	42.0
Oct.	35.5	16.7	26.1	--
Nov	26.7	11.6	19.15	4.0
Total rainfall (mm) 219.0				

Main-plot (NAA Levels)	Sub-plot (Crop growth stages)
L_1 = 0 ml ha^{-1}	S_1 = Seedling stage (25 days after sowing)
L_2 = 40 ml ha^{-1}	S_2 = Tillering stage (35 days after sowing)
L_3 = 80 ml ha^{-1}	S_3 = Booting stage (45 days after sowing)
L_4 = 120 ml ha^{-1}	
L_5 = 160 ml ha^{-1}	

Parameters recorded

The data on following parameters was recorded.

Number of leaves plant^{-1}

Green leaves per plant were counted at maturity in 5 plants randomly tagged in every sub-plot and their average was calculated.

Leaf area plant^{-1}

Leaf area was measured by calculating width and length of 5 leaves per plant randomly selected in every treatment by help of scale and averaged. The leaf area was measured in every treatment using formula:

Leaf area = Length of leaf × Width of leaf × Correction factor (0.75) × Number of leaves per plant

Correction factor for leaf area is called as potsaaium coefficient and values for sorghum is 0.75 (Musa *et al*., 2016).

Chlorophyll contents (μg cm^{-2})

Chlorophyll concentration was measured before heading. Five randomly plants were tagged from every sub plots. Photo SPAD meter was used for measurement of chlorophyll contents.

Fodder yield (kg ha^{-1})

Weight of total harvested material (1 m^2) in every plot was recorded and then converted to kilogram per hectare with the help of following formula:

Fodder yield (kg ha^{-1}) = Weight (1 m^2) × 10000

Benefit cost ratio (BCR)

BCR was calculated for every sub plot using the method proposed by Rahman *et al*. (2009) as under:

BCR = Benefits/ Expenditure

Statistical analysis

Data was recorded and examined by using ANOVA technique (Steel *et al.* 1997) with subsequent evaluation of distinct treatment means done (Black, 2011). ANOVA was accomplished using "Statistix 8.1" software.

Results and Discussion

Number of leaves plant^{-1}

Data analysis revealed that effect of different levels of NAA at various growth stages of sorghum and their interactions showed significant effects on No. of leaves (Table 1). Mean values of No. of leaves indicated that L_5 (160 ml NAA ha^{-1}) had the highest number of leaves (16.70 plant^{-1}) which are statistically at par with L_4 (120 ml ha^{-1}) NAA followed by L_1 (0 ml ha^{-1}), L_2 (40 ml ha^{-1}), L_3 (80 ml ha^{-1}), respectively. Numbers of leaves were recorded as the lowest (13.50 plant^{-1}) in L_0 (control plot). Mean values of growth stages revealed that NAA application at booting stage produced higher number of leaves (16.41 plant^{-1}) followed by S_2 (tillering stag), while S_1 (seedling stage) produced the lowest number of leaves (14.36 plant^{-1}). Interaction effect of NAA levels and crop growth stages revealed that S_3L_4 had highest No. of leaves (18.20 plant^{-1}), followed by L_4 (L_5S_3) x (L_5S_2), and the lowest No. of leaves (12.53 plant^{-1}) were recorded in L_0S_1 (control). Related results were found by Durrani *et al.* (2010) who reported that plant height at 40 days after sowing, number of leaves were recorded maximum. Durrani *et al.* (2010) and Almodares *et al.* (2011), described that yield and its components were increased with application of naphthalene acetic acid. Similar result was reported that decline in leaf production at 800 ppm could be attributed to the fact that at lower concentrations most plant growth regulators stimulated plant growth and at higher concentrations, inhibited plant growth (Basuchaudhuri, 2016).

Leaf area plant^{-1}

Data shown in Table 2 regarding leaf area (cm^2) per plant was affected significantly by various levels of naphthalene acetic acid and crop growth stages, however, their interactions were not significant. Mean values for the levels of naphthalene acetic acid revealed that L_5 (160 ml NAA ha^{-1}) had higher leaf area (411.98 cm^2) compared with other levels. The highest leaf area (375.27 cm^2) was recorded in S_3 (booting stage). When levels of naphthalene acetic acid increased, leaf area was also increased. Govindan *et al.* (2000) also conveyed similar findings and reported that plants sprayed with NAA (40 ppm) showed significantly increased leaf area (cm^2). Moreover, they stated that 150 + 60 ppm (IAA + NAA) gave the highest values of leaf area (cm^2). Similar results were found by Khan and Chaudhry (2006). Mona *et al.* (2013) concluded that various levels of naphthalene acetic acid significantly affected leaf area (cm^2), while different growth stages also produced variation in leaf area. Interactive effect of NAA levels and crop growth stages revealed that L_5S_3 produced maximum leaf area (419.07 cm^2) which is statistically similar to other treatments (Non-significant) and the lowest leaf area (402.87 cm^2) was recorded in L_0S_1. It may be due to the fact that leaf area is inherited character of specie and less influenced by exogenous application of materials.

Table 1: *Number of leaves plant^{-1} of hybrid sorghum as affected by NAA levels at different growth stages.*

Growth stages	NAA (levels)					Mean
	L_1 = 0	L_2 = 40	L_3 = 80	L_4 = 120	L_5 =160	
S_1 = Seedling stage	12.53 i	13.47 h	14.37 g	15.27 f	16.17 ce	14.36 c
S_2 = Tillering stage	13.40 h	14.33 g	15.23 f	16.00 de	16.73 bc	15.14 b
S_3 = Booting stage	14.57 g	15.63 ef	16.43 cd	18.20 a	17.20 b	16.41 a
Mean	13.50 d	14.48 c	15.34 b	16.49 a	16.70 a	

$LSD_{0.05}$ values; NAA levels= 0.44; Growth stages= 0.26; (L×S) interaction= 0.58; Means having similar letter (s) in each category are not significantly different at $P \geq 0.05$.

Table 2: *Leaf area (cm^2) of hybrid sorghum as affected by NAA levels at different growth stages.*

Growth stages	NAA (levels)					Mean
	L_1 = 0	L_2 = 40	L_3 = 80	L_4 = 120	L_5 =160	
S_1 = Seedling stage	NS 314.47	330.23	360.87	390.17	402.87	359.72 c
S_2 = Tillering stage	320.83	341.67	369.23	396.33	414.00	368.41 b
S_3 = Booting stage	323.00	357.47	379.27	397.53	419.07	375.27 a
Mean	319.43 c	343.12 c	369.79 b	394.68 a	411.98 a	

$LSD_{0.05}$ values; NAA levels= 24.01; Growth stages= 4.23; Means having similar letter (s) in each category are not significantly different at $P \geq 0.05$.

Table 3: *Chlorophyll contents (μg cm^{-2}) at 30 of hybrid sorghum as affected by NAA levels at different growth stages.*

Growth stages	NAA (levels)					Mean
	L_1 = 0	L_2 = 40	L_3 = 80	L_4 = 120	L_5 =160	
S_1 = Seedling stage	40.57 k	43.33 hi	44.37 fg	45.37 de	46.27 c	43.98 c
S_2 = Tillering stage	42.37 j	43.63 gh	44.60 ef	45.70 cd	46.87 b	44.63 b
S_3 = Booting stage	42.80 ij	43.70 gh	44.70 ef	47.90 a	47.40 ab	45.30 a
Mean	41.91 d	43.56 c	44.56 b	46.32 a	46.84 a	

$LSD_{0.05}$ values; NAA levels = 0.62; Growth stages = 0.26; Interaction = 0.58; Means having similar letter (s) in each category are not significantly different at $P \geq 0.05$.

Table 4: *Chlorophyll contents at 60 (μg cm^{-2}) days of hybrid sorghum as affected by NAA levels at different growth stages.*

Growth stages	NAA (levels)					Mean
	L_1 = 0	L_2 = 40	L_3 = 80	L_4 = 120	L_5 =160	
S_1 = Seedling stage	49.80	50.57	51.43	52.17	53.07	51.41 c
S_2 = Tillering stage	50.03	50.93	51.50	52.63	53.37	51.69 b
S_3 = Booting stage	50.43	51.37	51.90	54.57	54.07	52.47 a
Mean	50.09 c	50.96 b	51.61 b	53.12 a	53.50 a	

$LSD_{0.05}$ value; NAA levels = 0.68; Growth stages = 0.20; Interaction = 0.44; Means having similar letter (s) in each category are not significantly different at $P \geq 0.05$.

Table 5: *Fodder yield (kg ha^{-1}) of hybrid sorghum as affected by NAA levels at different growth stages.*

Growth stages	NAA (levels)					Mean
	L_1 = 0	L_2 = 40	L_3 = 80	L_4 = 120	L_5 = 160	
S_1 = Seedling stage	14390 g	14621 g	20000 f	30033 c	26967 d	21202 c
S_2 = Tillering stage	14546 g	18033 f	25233 de	36267 b	35817 b	25979 b
S_3 = Booting stage	14460 g	23765 e	32867 c	40350 a	39733 a	30235 a
Mean	14465 d	18806 c	26033 b	35550 a	34172 a	

$LSD_{0.05}$ values; NAA levels= 1638; Growth stages = 1270; (L×S) interaction= 2839; Means having similar letter (s) in each category are not significantly different at $P \geq 0.05$.

Chlorophyll contents at 30 days (µg cm^{-2})

Data analysis (Table 3) showed that naphthalene acetic acid at different crop growth stages and their interactions had significant effects on chlorophyll contents. Mean values indicated that NAA level L_5 (160 ml ha^{-1}) had maximum chlorophyll (46.84) which was statistically similar to L_4 (120 ml ha^{-1}) followed by L_3 (80 ml ha^{-1}) and L_2 (40 ml ha^{-1}). Minimum chlorophyll content (41.91) was recorded in L_1 (control). Mean values of crop growth stages revealed that S_3 (booting stage) produced maximum chlorophyll contents (45.30) followed by S_2 (tillering stage), while S_1 (seedling stage) produced minimum chlorophyll contents (43.98). Interaction of NAA levels and plant growth stages revealed that L_4S_3 produced the highest chlorophyll contents (47.90) followed by L_4S_2 and L_4S_1, respectively. Minimum chlorophyll content (40.57) was recorded in L_1 x S_1. It is further concluded that a higher levels of naphthalene acetic acid increase crop growth rate. Sivakumar *et al.* (2002) conveyed similar findings and reported that application of 20 ppm NAA increased chlorophyll in leaf of pearl millet. Begum *et al.* (2018) showed similar results and reported that different naphthalene acetic acid levels had significant effects on chlorophyll contents.

Chlorophyll contents at 60 days (µg cm^{-2})

Data analysis depicted that various levels of naphthalene acetic acid at crop growth stages and their interactions had significant effects on chlorophyll contents (Table 4). Mean values indicated that NAA level at L_5 (160 ml ha^{-1}) had maximum chlorophyll contents (53.50), which was statistically similar to S_4 (120 ml ha^{-1}) followed by L_3 (80 ml ha^{-1}) and L_2 (40 ml ha^{-1}). Minimum chlorophyll content (50.09) was recorded in L_1 (control). Mean values of crop growth stages of sorghum revealed that S_3 (booting stage) produced maximum chlorophyll contents (52.47) followed by S_2 (tillering stage), while S_1 (seedling stage) produced minimum chlorophyll contents (51.41). Interaction of NAA levels and plant growth stages revealed that L_4S_3 produced the highest chlorophyll contents (54.57), followed by L_4S_4 and L_4S_1, respectively. Minimum chlorophyll (49.80) was recorded in L_1 x S_1. Similar results were found by Viana *et al.* (2016). Begum *et al.* (2018) took similar conclusions and reported that different naphthalene acetic acid levels had significant effects on chlorophyll contents.

Table 6: *BCR of hybrid sorghum as affected by NAA levels at different growth stages.*

Plant growth regulator level + growth stages	Fodder yield (kg ha^{-1})	Total variable cost (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net income (Rs. ha^{-1})	BCR
L_1 (0 ml ha^{-1})	14465	0	36162	35910	252	0.007
L_2 (40 ml ha^{-1})	18806	33	47015	35943	11072	0.31
L_3 (80 ml ha^{-1})	26033	66	65082	35976	29106	0.80
L_4 (120 ml ha^{-1})	35550	99	88875	36009	52866	1.5
L_5 (160 ml ha^{-1})	34172	132	85430	36042	49388	1.37
S_1 (Seedling)	21202	0	53005	35910	17095	0.47
S_2 (Tillering)	25979	0	64947	35910	29037	0.80
S_3 (Booting)	30235	0	75587	35910	39677	1.10
$L_1 \times S_1$	14390	0	35975	35910	65	0.002
$L_1 \times S_2$	14546	0	36365	35910	455	0.013
$L_1 \times S_3$	14460	0	36150	35910	240	0.007
$L_2 \times S_1$	14621	33	36552	35943	609	0.02
$L_2 \times S_2$	18033	33	45082	35943	9140	0.25
$L_2 \times S_3$	23765	33	59412	35943	23469	0.65
$L_3 \times S_1$	20000	66	50000	35976	14024	0.39
$L_3 \times S_2$	25233	66	63082	35976	27106	0.75
$L_3 \times S_3$	32867	66	82167	35976	46191	1.28
$L_4 \times S_1$	30033	99	75082	36009	39073	1.08
$L_4 \times S_2$	36267	99	90667	36009	54659	1.51
$L_4 \times S_3$	40350	99	100875	36009	64866	1.80
$L_5 \times S_1$	26967	132	67417	36042	31375	0.87
$L_5 \times S_2$	35817	132	89542	36042	53500	1.48
$L_5 \times S_3$	39733	132	99332	36042	63290	1.75

Fodder yield (kg ha^{-1})

Data analysis (Table 5) indicated that effect of naphthalene acetic acid at different crop growth stages and their interactions had significant effects on fodder yield (kg ha^{-1}). Mean values indicated that NAA level of L_4 (120 ml ha^{-1}) had maximum fodder yield (35,550 kg ha^{-1}) which was statistically same as L_5 (160 ml ha^{-1}) followed by L_3 (80 ml ha^{-1}) and L_2 (40 ml ha^{-1}), respectively. Minimum fodder yield (13,024 kg ha^{-1}) was recorded in L_1 (control). Mean values of crop growth stages of sorghum revealed that S_3 (booting stage) produced maximum fodder yield (29,931 kg ha^{-1}) followed by S_2 (tillering stage), while S_1 (seedling stage) produced minimum fodder yield (20,897 kg ha^{-1}). Interaction of NAA levels and plant growth stages revealed that L_4S_3 produced the highest fodder yield (40,350 kg ha^{-1}) followed by L_4S_2 and L_4S_1, respectively. Minimum fodder yield (12,867 kg ha^{-1}) was recorded in L_1S_1. The above treatments provided the balanced supply of all essential nutrients through growth regulator which synchronized with crop needs and uptake and thus, resulted in significantly higher fodder yield as compared to other treatments. The yield advantage might be due to the fact that the application of growth regulator has increased the sufficient quantity of essential nutrient which finally resulted in increased components and fodder yield (Gemici, 2003). The results are in line by Ullah *et al.* (2007). The results are also in line with Almodares *et al.* (2011) and Basuchaudhuri (2016) who reported that with increased level of NAA also directly contributed in the vegetative parts i.e. leaf area, size etc. enhancement which ultimately benefit the fodder yield.

Benefit cost ratio (BCR)

Data presented in Table 6 showed economic analysis of fodder hybrid of sorghum as affected by various levels of NAA and its growth stages. Cost of production and other economic details are given in Table 6. It is clear that L_4S_3 had the maximum net income (Rs. 64,866 ha^{-1}) with BCR 1.8, while minimum L_1S_1 was noted (Rs.35,910) net profit with BCR 0.002. The second highest net income was calculated (Rs. 63,290) with BCR 1.75 in L_5S_3.

Conclusions and Recommendations

Foliar application of naphthalene acetic acid (120 ml ha^{-1}) produced more leaves and the highest fodder yield (35,550 kg ha^{-1}) at booting stage, while all other stages of sorghum had lower fodder yield. Therefore, it is concluded that booting stage is suitable for high fodder sorghum yield with 120 ml NAA ha^{-1} in Dera Ismail Khan.

Novelty Statement

Pakistan lying in that geographic area which is pound to climate change scenario and this climate change causes reduction in vegetative and economical yield of our summer crops. Considering the importance of naphthalene acetic acid (PGR) in reclaiming the climate change in physiology of sorghum the present research is designed accordingly.

Author's Contribution

Iqtidar Hussain: Principal investigator, technical help, overall management of the article.
Muzafar Ali: Co-principal investigator, data collection.
Imam Bakhsh: Farm manager, technical input.
Muhammad Waqas Imam Malik: Co-principal investigator, data collection, did SPSS analysis.

Conflict of interest

The authors have declared no conflict of interest.

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