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Nutrient management strategies for improved growth attributes in sweet sorghum

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Abstract

The present field investigation (*kharif* 2021 and 2022) studied the effect of nutrient management systems on growth attributes of sweet sorghum involving three levels of nitrogen (N) (60,120,180 kg/ha), two levels of potassium (K) (40,60 kg/ha), two levels of boron (B) (1, 2 kg/ha), recommended dose of NPK (120:60:40), RDF + FYM @ 10t/ha and an absolute control in a randomized complete block design. Application of NKB at the rate of 180, 60 and 2 kg/ha resulted in considerably higher values for plant height, stem diameter, number of tillers/m^2, average internode number and internode length/stem throughout the cropping seasons (30, 60, 90 days after sowing and at harvest). Similarly, correlation studies revealed that growth attributes such as plant height, stem diameter, tillers/m^2, internode number and length were positively correlated with juice yield of sweet sorghum. The findings highlighted the significance of balanced fertilization particularly high N application in enhancing sweet sorghum growth.

Keywords: Boron, Nitrogen, Potassium, Stem diameter

Sorghum (*Sorghum bicolor* (L.) Moench), a member of *Poaceae* family is a C_4 plant with cultivation area of 40.7 million hectares, production of around 57.5 t/ha and an average productivity of 1.41 t/ha globally (FAOSTAT, 2025). Similarly, the sorghum has widespread cultivation across India with cultivated area of 3.8 million hectares and production is around 4.1 million tons (FAOSTAT, 2025). Sweet sorghum, a sugar rich variant of sorghum can be characterized for substantially higher biomass production (55-150 t/ha), stem sugar accumulation (16-22%), water use efficiency (310 kg water/kg of dry matter), drought tolerance and wider adaptability across various edaphic and environmental conditions (Xiao *et al*. 2021). Such attributes of sweet sorghum have risen its candidature as bioethanol feedstock in biofuel industry (Kanbar *et al*. 2021). Furthermore, being a C_4 plant, sweet sorghum has considerable potential to act as prominent carbon sink with considerable absorption of atmospheric carbon dioxide in its biomass and produce environment friendly biofuels with high-octane rating and low sulphur content in its fuel (Kaur *et al*. 2024).

Optimized nutrient application via organic or inorganic nutrient sources is one of the key primary production practices responsible for optimized crop growth and productivity (Singh and Pathania 2020; Sharma *et al*. 2020; Naik *et al*. 2024). Among crop nutrients, nitrogen has a significant importance while influencing vegetative growth of crop plants with its substantial role in enhanced photosynthesis, chlorophyll, protein and carbohydrate production in plant biomass (Sharma *et al*. 2018). Enhanced synthesis of photosynthates or carbohydrates is further supported by translocation across plant biomass with potassium and boron in sugar crops (Shah *et al*. 2024). Especially, boron with its ability to form sugar-borate complexes helps in ease in transport of sugars across cell membranes. Therefore, an integrated approach involving application of nitrogen, potassium and boron is critical for enhanced growth of crops such as sweet sorghum with significantly higher biomass production potential. Several scientific investigations have

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reported positive significant effects of nutrient management practices on growth attributes of sweet sorghum. A field study by Olugbemi *et al*. (2018) reported considerable improvements in plant height of sweet sorghum with nitrogen application at the rate of 120 kg/ha. Considering such a positive influence of nutrient management practices on growth of sweet sorghum reported earlier by various researchers (Villaruben *et al*. 2022) and lack of considerable scientific information on effect of nutrient management systems over growth of sweet sorghum especially in north-western Himalayan region, the present study was conducted with the objective to study the effect of nutrient management practices on growth attributes of sweet sorghum.

Materials and methods

The field experiments were conducted during *kharif* seasons of 2021 and 2022 under the mid-hill conditions of Himachal Pradesh at Research farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh. The experimental site was situated in the Palampur valley at 32°6 'N latitude, 76°3' E longitude on an elevation of 1290.8 meter above mean sea level in the District Kangra of Himachal Pradesh. According to agroclimatic zones of Himachal Pradesh, the site falls under mid-hill sub-humid zone of the North-Western Himalayas in the Palam valley of District Kangra, Himachal Pradesh, India. The soil at the experimental site was silty clay loam in texture (Sand = 34.18%, Silt = 36.78%, Clay = 27.5%), acidic in reaction (pH = 5.48), having medium soil available nitrogen (256.4 kg/ha), phosphorus (17.20 kg/ha) and high potassium (170.6 kg/ha) content. The experiment was laid out in randomized complete block design with 15 treatments which were replicated thrice. The treatments were T_1: N_{60} K_{40} B_1, T_2: N_{60} K_{40} B_2, T_3: N_{60} K_{60} B_1, T_4: N_{60} K_{60} B_2, T_5: N_{120} K_{40} B_1, T_6: N_{120} K_{40} B_2, T_7: N_{120} K_{60} B_1, T_8: N_{120} K_{60} B_2, T_9: N_{180} K_{40} B_1, T_{10}: N_{180} K_{40} B_2, T_{11}: N_{180} K_{60} B_1, T_{12}: N_{180} K_{60} B_2, T_{13}: Recommended dose of NPK (120: 60: 40), T_{14}: Recommended dose of NPK + FYM @10 t/ha and T_{15}: Absolute control.

The crop variety used was SSV 84 being sown at a spacing of 45 × 15 cm using seed rate of 8 kg/ha. The observations were recorded on plant height, number of tillers, internode length and number of internodes per stem using randomly five selected and tagged plants.

The data was subjected to statistical analysis using R version 4.3.2. The post hoc mean separation test employed was Least Significant Difference (LSD). The correlation studies for the juice yield and growth attributes of sweet sorghum were derived using R version 4.3.2 based packages such as “Corrplot” and “Hmisc”.

Results and discussions

Plant height was significantly influenced during the cropping seasons of 2021 and 2022 under the influence of various nutrient management systems at various observational stages such as 30, 60, 90 DAS and at harvest (Table 1). A continuous increase in plant

Table 1: Effect of nutrient management systems on plant height

Nutrient Management Systems	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2021	2022	2021	2022	2021	2022	2021	2022
N_{60} K_{40} B_1	27.9	42.3	118.9	118.8	187.8	194.0	207.0	195.0
N_{60} K_{40} B_2	28.5	44.1	120.2	122.2	194.0	197.2	211.4	203.9
N_{60} K_{60} B_1	35.0	45.9	127.3	125.4	205.7	218.7	225.0	216.8
N_{60} K_{60} B_2	35.0	46.5	129.8	126.7	210.2	222.4	231.5	218.9
N_{120} K_{40} B_1	46.1	47.5	148.1	156.1	251.3	268.7	271.8	275.6
N_{120} K_{40} B_2	47.6	48.3	148.7	159.8	254.1	270.0	275.3	279.1
N_{120} K_{60} B_1	47.6	48.8	151.3	162.3	259.8	273.0	277.7	284.2
N_{120} K_{60} B_2	48.1	48.9	152.0	162.7	264.9	274.9	278.3	288.4
N_{180} K_{40} B_1	52.1	51.9	160.2	173.1	276.1	282.3	284.9	295.3
N_{180} K_{40} B_2	53.1	55.3	162.8	175.1	284.3	286.7	287.7	296.4
N_{180} K_{60} B_1	53.7	57.5	164.3	179.4	281.1	289.0	289.1	298.8
N_{180} K_{60} B_2	54.5	59.7	165.3	183.6	282.3	291.7	291.3	300.4
RDF NPK (120: 60: 40)	41.7	47.1	141.4	140.4	229.1	235.3	252.3	238.4
RDF+ FYM @10 t/ha	50.8	50.1	156.7	153.1	264.2	279.3	276.4	293.3
Control	24.1	40.9	113.3	109.7	178.2	180.7	210.0	189.9
SEm±	2.01	2.16	6.63	7.77	11.67	13.92	12.58	13.82
LSD (p = 0.05)	5.86	6.31	19.32	22.65	33.80	40.33	36.44	40.26

height was observed with the increasing crop duration. During both the cropping seasons of 2021 and 2022, the tallest plants were recorded with the application of nitrogen, potassium and boron at the rate of 180, 60 and 2 kg/ha at all the observational stages i.e., 30, 60, 90 DAS and at harvest. Among the three nutrients, response to N application was more pronounced than to K and B. Between the latter two nutrients, crop exhibited more response to K than to B. An integrated approach based on application of recommended dose of fertilizers (N:P: K; @ 120:60:40 kg/ha) along with farm yard manure (10 t/ha) resulted in statistically comparable plant height of sweet sorghum. The treatments based on lower nitrogen application rate of 60 kg/ha along with potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in comparatively shorter plants. The shortest crop plants were observed in the treatment wherein exogenous application of plant nutrients was completely abstained.

Substantially higher plant height of sweet sorghum with the application of higher nitrogen application rate of 180 kg/ha along with balanced fertilization involving potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) can be attributed to substantial nutrient availability in soil solution leading to enhanced photosynthate accumulation leading to cell elongation, cell division and differentiation into newer plant tissues leading to increased plant height (Hilty *et al*. 2021; Chandel *et al*. 2023). The results of the present investigation can be supported by the findings of Villaruben *et al*. (2022) wherein they observed substantial improvement in plant height of sweet sorghum with the balanced fertilizer approach based on application of nitrogen (120 kg/ha), phosphorus (40 kg/ha), and potassium (45 kg/ha). Similarly, another field study by Abdelhameid (2020) reported considerably improvements in plant height of sweet sorghum with application of potassium at the rate of 115 kg/ha.

The data on number of tillers/m^2 has been recorded at various observational stages i.e., 30, 60, 90 DAS and at harvest (Table 2). Number of tillers/m^2 were significantly influenced with the various experimental treatments imposed. Application of nitrogen, potassium and boron at the rate of 180, 60 and 2 kg/ha resulted in the highest number of tillers/m^2, however, treatments based on higher nitrogen application rate of 180 kg/ha along with balanced fertilization of

Table 2: Effect of nutrient management systems on number of tillers per meter square

Nutrient Management Systems	Number of tillers per meter square							
	30 DAS		60 DAS		90 DAS		At harvest	
	2021	2022	2021	2022	2021	2022	2021	2022
$N_{60}K_{40}B_1$	19.7	20.1	22.3	22.5	25.6	26.4	27.2	27.7
$N_{60}K_{40}B_2$	20.4	20.8	22.7	23.1	26.1	26.6	27.7	28.2
$N_{60}K_{60}B_1$	20.5	20.8	23.1	23.5	26.6	27.1	28.2	28.7
$N_{60}K_{60}B_2$	21.1	21.5	23.7	24.1	27.2	27.7	28.9	29.4
$N_{120}K_{40}B_1$	22.1	22.5	24.7	25.1	28.0	28.5	29.8	30.3
$N_{120}K_{40}B_2$	22.4	22.8	25.1	25.6	28.9	29.4	30.7	31.2
$N_{120}K_{60}B_1$	22.5	22.9	25.5	25.9	29.3	29.8	31.1	31.6
$N_{120}K_{60}B_2$	23.1	23.5	26.1	26.6	30.0	30.6	31.8	32.4
$N_{180}K_{40}B_1$	23.8	24.6	26.6	27.2	30.6	31.3	32.4	33.4
$N_{180}K_{40}B_2$	23.8	24.5	26.9	27.7	30.9	31.8	32.8	33.7
$N_{180}K_{60}B_1$	23.8	24.6	26.9	27.7	31.1	32.0	32.7	33.6
$N_{180}K_{60}B_2$	24.4	25.1	27.5	28.2	31.8	32.7	33.1	34.1
RDF NPK (120: 60: 40)	22.7	23.1	25.7	26.1	29.5	30.0	30.7	31.2
RDF+ FYM @10 t/ha	23.7	24.1	26.7	27.2	30.7	31.3	32.6	33.2
Control	18.5	18.9	20.9	21.0	23.7	23.8	25.2	25.3
SEm±	0.5	0.5	0.6	0.5	0.6	0.6	0.6	0.5
LSD (p = 0.05)	1.4	1.4	1.7	1.6	1.8	1.7	1.8	1.6

potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in statistically comparable results. Optimized nutrient supply with nitrogen, potassium and boron may have resulted in increased soil solution nutrient availability and thus enhanced size and number of meristematic cells (officinale Rosc, 2016; Sharma and Sharma 2020). Furthermore, role of nutrient elements such as nitrogen may have promoted enhanced cytokinin concentration responsible for improved cell size, cell wall expansion, formation of new cells and ultimately their differentiation into new tissues (Wu *et al*. 2021). Nutrient management systems based on application of nitrogen at the rate of 60 kg/ha along with balanced fertilization of potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in comparatively lower number of tillers/m^2. The lowest number of tillers/m^2 were recorded for the absolute control. The results of the present investigation were in parallel with the findings reported by Bashir *et al*. (2023) wherein potassium was found to significantly enhance tiller formation in wheat.

Stem diameter

The data on stem diameter has been recorded at various observational stages i.e., 30, 60, 90 DAS and at harvest (Table 3). Stem diameter was observed to be significantly influenced with the various experimental treatments imposed. Application of nitrogen, potassium and boron at the rate of 180, 60 and 2 kg/ha resulted in the thickest stems, however treatments based on higher nitrogen application rates of 180 and 120 kg/ha along with balanced fertilization of potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in statistically comparable results in terms of stem diameter. Considerably better stem diameter with the nutrient management systems based on higher nitrogen application rates can be attributed to substantially improved chlorophyll content, and photosynthetic activity leading to enhanced production and assimilation of photosynthates or carbohydrates in crop stem (Sharma *et al*. 2014). Nutrient management systems based on application of nitrogen at the rate of 60 kg/ha along with balanced fertilization of potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in comparatively lower stem diameter. The lowest stem diameter was observed in the absence of exogenous nutrient application i.e., absolute control.

The data on internode length for 2021 and 2022 cropping seasons has been presented in the Table 4. A perusal of the data revealed that internode length was significantly influenced with the application of nutrient management systems and absolute control. During both the cropping seasons of 2021 and 2022, the highest internode length was observed under the

Table 3. Effect of nutrient management systems on stem diameter

Nutrient Management Systems	Stem diameter (cm)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2021	2022	2021	2022	2021	2022	2021	2022
$N_{60}K_{40}B_1$	0.38	0.40	0.88	0.91	0.96	0.99	1.50	1.51
$N_{60}K_{40}B_2$	0.44	0.43	0.98	0.97	0.99	1.09	1.55	1.57
$N_{60}K_{60}B_1$	0.45	0.48	0.99	1.03	1.12	1.16	1.61	1.62
$N_{60}K_{60}B_2$	0.49	0.54	1.05	1.09	1.19	1.20	1.65	1.66
$N_{120}K_{40}B_1$	0.60	0.61	1.46	1.45	1.46	1.47	1.95	1.97
$N_{120}K_{40}B_2$	0.61	0.64	1.47	1.47	1.47	1.49	1.96	2.00
$N_{120}K_{60}B_1$	0.62	0.63	1.49	1.49	1.47	1.51	2.00	2.04
$N_{120}K_{60}B_2$	0.65	0.67	1.50	1.50	1.53	1.54	2.02	2.05
$N_{180}K_{40}B_1$	0.64	0.68	1.51	1.52	1.60	1.58	2.07	2.10
$N_{180}K_{40}B_2$	0.66	0.69	1.53	1.53	1.58	1.59	2.11	2.15
$N_{180}K_{60}B_1$	0.68	0.70	1.54	1.53	1.58	1.59	2.14	2.18
$N_{180}K_{60}B_2$	0.67	0.70	1.56	1.54	1.59	1.60	2.13	2.21
RDF NPK (120: 60: 40)	0.55	0.56	1.35	1.36	1.36	1.41	1.83	1.87
RDF+ FYM @10 t/ha	0.67	0.68	1.51	1.51	1.54	1.57	2.04	2.07
Control	0.33	0.34	0.80	0.90	0.93	0.97	1.32	1.33
SEm±	0.03	0.03	0.05	0.06	0.05	0.06	0.08	0.10
LSD ($p = 0.05$)	0.08	0.08	0.14	0.16	0.14	0.19	0.24	0.28

Table 4: Effect of nutrient management systems on internode length and number of internodes per stem

Nutrient Management Systems	Length of internode (cm)		Number of internodes per stem	
	2021	2022	2021	2022
$N_{60} K_{40} B_1$	15.7	16.7	8.7	9.8
$N_{60} K_{40} B_2$	15.8	17.0	8.7	10.0
$N_{60} K_{60} B_1$	16.6	17.7	8.8	10.2
$N_{60} K_{60} B_2$	16.9	17.9	9.0	10.4
$N_{120} K_{40} B_1$	17.7	19.0	9.2	11.0
$N_{120} K_{40} B_2$	17.9	19.1	9.2	11.1
$N_{120} K_{60} B_1$	18.1	19.1	9.2	11.2
$N_{120} K_{60} B_2$	18.1	19.3	9.3	11.2
$N_{180} K_{40} B_1$	18.7	20.0	9.3	11.4
$N_{180} K_{40} B_2$	18.8	20.1	9.5	11.6
$N_{180} K_{60} B_1$	18.9	20.1	9.5	11.7
$N_{180} K_{60} B_2$	19.0	20.3	9.7	11.9
RDF NPK (120: 60: 40)	17.2	18.4	10.0	10.6
RDF+ FYM @10 t/ha	18.0	19.2	9.5	11.2
Control	12.3	13.2	8.2	9.7
SEm±	1.01	0.75	0.43	0.46
LSD (p = 0.05)	2.94	2.17	1.24	1.35

influence of integrated application of nitrogen, potassium and boron at the rate of 180, 60 and 2 kg/ha, respectively. Similarly, nutrient management systems based on application of nitrogen at higher rates i.e., 120 and 180 kg/ha along with balanced fertilization of potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in statistically comparable internode length for sweet sorghum. Conjunctive application of RDF + FYM (10 t/ha) resulted in at par internode length with nutrient management systems based on higher nitrogen application rates (120 and 180 kg/ha). Considerable improvements in internode length under the influence of optimized and balanced nutrient supply can be attributed to enhanced meristematic activity as well as elevated activity of endogenous plant hormones such as cytokinin (Jia *et al*. 2022). The lowest internode length was recorded in the absolute control wherein no external supply of nutrients was done. Poor response with absolute control was due to lack of external supply of crop nutrients.

The data on number of internodes for 2021 and 2022 cropping seasons has been presented in the Table 4. A perusal of the data revealed that number of internodes were significantly influenced with the nutrient management systems and absolute control. Parallel to internode length, application of nitrogen, potassium and boron at the rate of 180, 60 and 2 kg/ha was found to be responsible for significantly higher number of internodes per stem for sweet sorghum. During 2021 and 2022 cropping seasons, nutrient management systems based on application of nitrogen at higher rates (120 and 180 kg/ha) along with balanced fertilization of potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) resulted in significantly higher number of internodes per stem as compared to the absolute control.

Correlation studies

The correlation studies for juice yield and growth attributes of sweet sorghum revealed significant positive correlation for the investigated parameters. Growth attributes of sweet sorghum such as plant height (r = 0.90), stem diameter (r = 0.93), tiller count/m^2 (r = 0.92), internode length (r = 0.98) and count (r = 0.89) were found to be positively correlated with juice yield.

The terms mentioned in the correlation plot are given as:

JY = Juice yield, PH = Plant height, SD = Stem diameter, Tiller = Tiller count/m^2, IL = Internode length, IC = Internode count

Conclusion

Based on the present investigation, it can be

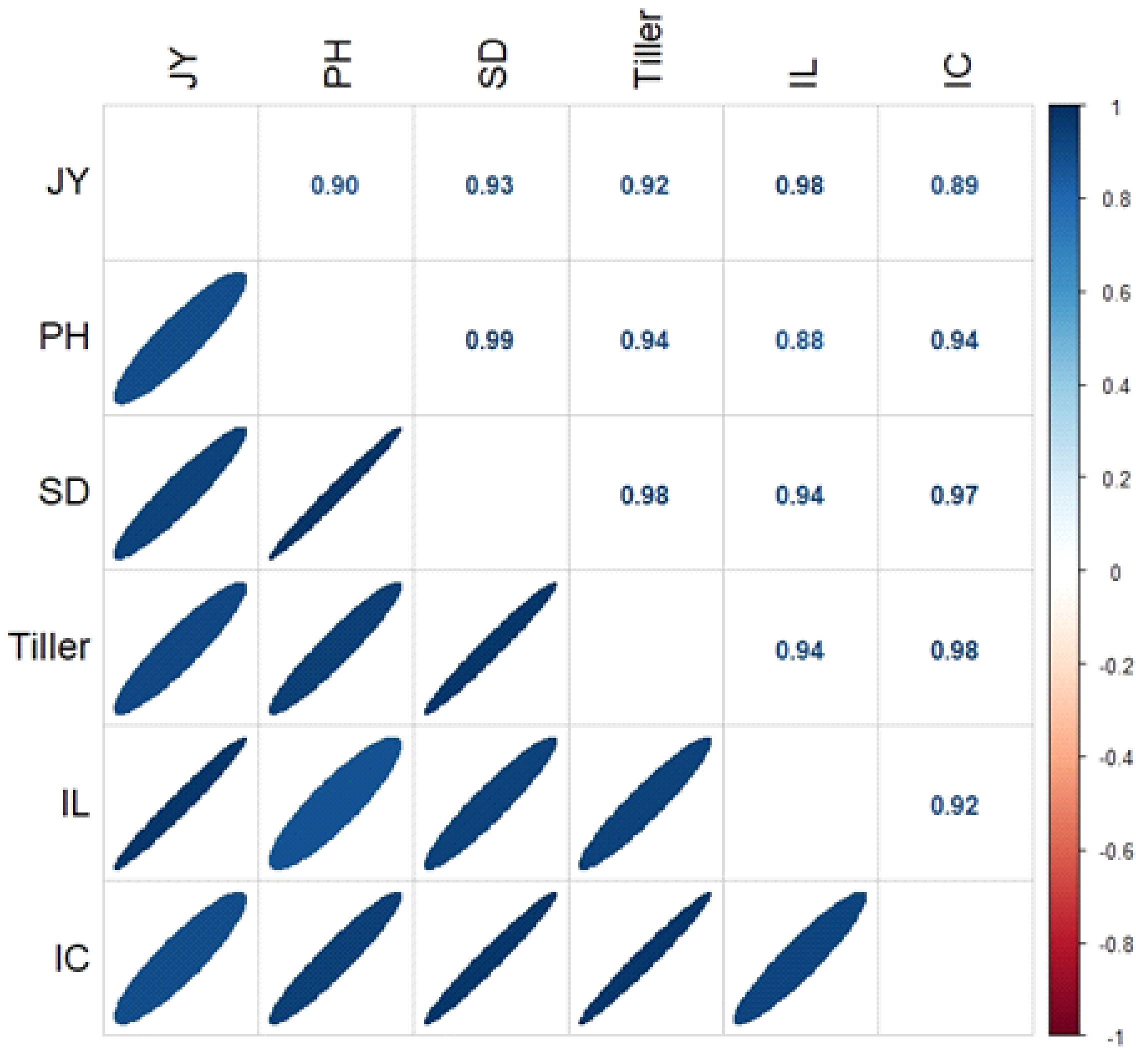

Fig 1. Correlation studies between juice yield and growth attributes of sweet sorghum

concluded that application of nitrogen at the rate of 120 or 180 along with balanced fertilization of potassium (40 and 60 kg/ha) and boron (1 and 2 kg/ha) can considerably improve the growth of sweet sorghum with benign effect observed in terms of plant height, stem diameter, number of tillers/m^2, internode length and number. The findings highlight the critical importance of balanced fertilization, particularly with higher nitrogen application, in enhancing sweet sorghum growth.

Conflict of interest: The authors declare no conflict of interest in relation to this review article.

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