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Response of cool-season turfgrass to a new plant growth regulator

Supervisor
Dr. Cristina Pornaro

Co-supervisor
Prof. Dr. Stefano Macolino

Submitted by,

Ankit Kumar Sahu

Matricola: 2044044

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Abstract:

Plant growth regulators (PGRs) are a useful tool for turfgrass management. Plant growth regulators have been used for many years to manage turf grass, with the goal of reducing mowing frequency and achieving the best visual score . The aim of this study was to investigate the efficacy of the PGR Primo Maxx II and ATTRAXOR on reducing the vertical growth of *Lolium perenne* /*Poa pratensis* turfgrass and *Poa annua* seedhead formation. The results of this study demonstrated that the ATTRAXOR can perform well or at par with the already available plant growth regulator Primo Maxx II. The trial included the parameters like, color, quality, NDVI, germination, daily growth rate, temperature, precipitation and biomass. The experiment was conducted over a period of 2 years, comparing the ATTAXOR and Primo MAX II from March 2023 to March 2025. This study provides valuable insights into the performance of the Plant Growth Regulator (PGR) ATTRAXOR during the spring and fall season. The results showed that the treatments had a significant impact on the *Lolium perenne* /*Poa pratensis* turfgrass and *Poa annua* seedhead formation, as indicated by the statistical analysis.

Introduction

1. PLANT GROWTH REGULATORS

Plant growth regulators (PGRs), such as auxins, cytokinins, gibberellins, abscisic acid, ethylene, and substances with similar biological effects, are chemicals used in modern agriculture, horticulture and viticulture to facilitate crop management and improve yield and quality of the harvested produce Agudelo-Morales et al., 2021. These regulators are classified into two categories: true plant growth regulators, which interfere directly with the plant's hormonal status; and 'atypical' plant growth regulators, which act by displaying a local and/or transient phytotoxic effect Agudelo-Morales et al., 2021. Furthermore, new naturally occurring substances with phytohormonal-like regulatory roles, such as polyamines, oligosaccharins, salicylates, jasmonates, sterols, brassinosteroids, dehydrodiconiferyl alcohol glucosides, turgorins, systemin, unrelated natural stimulators, and inhibitors, are constantly being discovered and synthesized (Gaspar et al., 1996). A better knowledge of the uptake, transport, metabolism, and mode of action of phytohormones has increased our understanding of their role in growth and development (Gaspar et al., 1996). Plant growth regulators are used to induce roots, control flowering, sex, and aging, as well as increase the latex flow in rubber trees, ripen sugarcane, control sprouting in onions and potatoes, shorten and strengthen wheat stems, prevent premature deterioration, and control timing for maximum utilization of crops ("Plant Growth Regulators," n.d.). They play an increasingly important role in energy conservation due to their ability to increase yields (“Plant Growth Regulators,” n.d.). It is clear that PGRs should occupy an increasingly important role in agriculture (“Plant Growth Regulators,” n.d.).1.1. Different types of plant growth regulators. There are two types of PGRs: natural and synthetic. Natural PGRs are found in plants and consist of hormones, hormones-like substances, and other substances. Synthetic PGRs are produced in the laboratory and can be used to control plant growth, development, and productivity (Gaspar et al., 1996). Although many PGRs have been evaluated, only a few are used commercially (Mohamed et al., 2000). The use of PGRs has been largely limited to controlling plant growth (“Plant Growth Regulators,” n.d.). In recent years, the focus has shifted to the biochemical and physiological aspects of PGRs (Roberts, 2012). The terms “plant growth regulator” and “plant bioregulator” are used interchangeably to refer to a chemical that can increase or reduce Agudelo-Morales et al., 2021 plant growth. This book focuses on the application of PGRs in agriculture and horticulture and provides an overview of their biochemical and physiological processes (Basra, 2000). Different types of PGRs control plant growth, such as leaf growth and development, flowering, fruit set, and fruit growth and ripening (Trigiano & Gray, 2004). In Florida, the use of PGRs is regulated with the definition of the term “plant growth regulator” and a list of approved PGRs (Fishel, 2006). The term “auxin” is used to refer to most PGRs, including gibberellins (West, 1960). Synthetic PGRs can be produced through fermentation or synthetically, and are used in plant tissue culture media (George et al., n.d.).

1.1 Plant growth regulators are used in turfgrass management

Plant Growth Regulators are a type of plant bioregulator used in turfgrass management (Rademacher, 2015). These synthetic compounds affect the regular growth of plants, and are usually administered through the soil or as a foliar spray (Singh et al., 2020). For example, Chlormequat Chloride (CCC) is a growth regulator that has been developed to act as an anti-lodging agent and to serve as a growth regulator (Faria et al., 2015). It is often used in cereals, grasses, and rice, and interacts with environmental factors and intra-specific competition (Reddy et al., 1995; Basra, 2000). Moreover, the gibberellin-like PGRs are used to suppress the growth of grasses by disrupting gibberellin biosynthesis (Watschke et al., 2015). This kind of knowledge can be used to effectively manage trees in urban landscapes (Moore, 1998). However, it is important to be careful when using PGRs to regulate plant growth as it can affect not only the plant, but also the herbivores and the parasitoids (Zhao et al., 2017; Strydhorst et al., 2018). Therefore, an understanding of PGRs is important for turfgrass management, and can be a useful risk management tool.

2. ROLE AND BENEFITS OF PLANT GROWTH REGULATORS IN GENERAL AND IN TURFGRASS MANAGEMENT

As PGRs are now used in both natural and synthetic forms, understanding their effects is a key to taking advantage of their potential for use in agriculture and horticulture (Gaspar et al., 1996; Mohamed et al., 2000). Plant growth regulators are known to control a wide range of physiological and developmental processes ("Plant Growth Regulators," n.d.). For instance, they can have an impact on plant growth and development, flowering, fruit set, and fruit growth and ripening (Trigiano & Gray, 2004). In the past few years, the focus has shifted from their potential uses to a better understanding of their effects (Roberts, 2012). The usage of the term "plant bioregulator" is preferred over "plant growth regulator" to describe their impacts Agudelo-Morales et al., 2021, as it is a more precise way to describe their effects. Considering their use in agriculture and horticulture, this book combines a comprehensive description of the applications of PGRs with an understanding of their biochemical and physiological modes of action (Basra, 2000). Furthermore, the term "plant growth regulator" has been defined in the literature (Fishel, 2006), and the term "auxin" is used to include most plant growth regulators, even the gibberellins (West, 1960). Additionally, some of the natural growth substances are prepared synthetically or through fermentation (George et al., n.d.). All of this is indicative of the vast potential of PGRs and their ability to be used to improve crop yield.Plant growth regulators, such as abscisic acid (ABA) and trans-zeatin (TE), are natural products that have been used for decades in turf management. The application of PGRs provides multiple benefits, including reduced evapotranspiration during drought conditions and increased photosynthetic efficiency, which is a major factor in drought resistance (Elansary & Yessoufou, 2015). Furthermore, PGRs can improve turf quality, leaf photochemical efficiency, maximum root length, dry weight, total nonstructural carbohydrates, and Ca and K contents (Elansary & Yessoufou, 2015). The application of PGRs is an effective and economical way to maintain a healthy and aesthetically pleasing turf. Moreover, the use of PGRs is advantageous in that it provides a natural way to manage turf growth while avoiding the risk of chemical residues from synthetic pesticides. As a result, PGRs are becoming increasingly popular in turf management practices.Plant growth regulators have been proven to be a reliable method of attaining sustainable turf management (Watschke et al., 2015). This is due to the fact that they are less time-consuming to treat the plant (March et al., 2013), and they are environmentally friendly (Long, 2006). Reviews of growth regulation in turfgrass science have shown that PGRs have the potential to improve turf in shaded conditions Steinke, Kurt & Stier, J.. (2003). This has been demonstrated by the high photochemical efficiency (Fv:Fm > 0.8) in all three species Steinke, et al., 2003). In addition, PGRshave been found to have a profound impact on turfgrass management practices (Long, 2006). For instance, increasing nitrogen rates has been found to increase the efficacy of plant growth regulators for clipping reduction (Long, 2006). Moreover, PGRs have also been found to increase the effectiveness of fungicides (*Plant Disease 1996 | Interactive Effects of Plant Growth Regulators and Fungicides. On Epidemics of Dollar Spot in Creeping Bentgrass*, n.d.) thus making them an important tool for successful turfgrass management (Baldwin et al., 2009). Further research is needed to investigate if greater drought tolerance of subsurface drip–irrigated turf is the result of increased water-use efficiency due to altered root morphology (Schiavon et al., 2014). As PGRs have the potential to resist drought (Elansary & Yessoufou, 2015), they are essential for successful turfgrass management (Baldwin et al., 2009) and they have also been observed to affect Poa annua biotype turf quality (Williams, 2014).

2.1. Plant growth regulators affect plant growth, development and crop management

Plant growth regulators are substances that have a range of effects on plant growth and development. Different substances have different biochemical modes of action Nauen, Ralf & Bretschneider, Thomas. (2002), with some acting as inhibitors of induced mutations Kada, Tsuneo & Shimoi, Kayoko (1987). The primary stage of a substance's mode of action is often difficult to distinguish from the secondary stage (Maris, 1995), and molecular mechanisms of trichothecenes have been studied in relation to their mode of action (Ueno, 1978). In addition, a response profile has been created for compounds with unknown modes of action

(Duke, 2011), and the biological action of bacteria and lipopeptides produced by them has been proposed as a mode of action (Marrone, 2002). Agents suppressing cellular mutagenesis have been analyzed in bacteria genetics (Kada et al., 1986), and the toxic mode of action of nanosilver has been evaluated in vivo (Völker et al., 2012). Vaccines have also been formulated to make them more effective (Cox & Coulter, 1997). These findings have provided a better understanding of the various biochemical modes of action of PGRs and their effects on plant growth and development. Plant growth regulators are becoming increasingly more popular in the field of agriculture, especially for controlling the frequency of mowing (Rademacher, 2015). Their application can influence a range of plant characteristics, such as height, flowering, and seeding (Watschke et al., 2015). However, the effects of PGRs vary depending on the species of plant (Singh et al., 2020). For example, the PGRs are effective in controlling the growth of cereal crops, rice, and turf (Faria et al., 2015). It is also possible to use MC models to optimize the PGR application on farms (Reddy et al., 1995). The availability of sophisticated methods for identifying and measuring the PGRs has provided a powerful tool for manipulating plant growth (Basra, 2000). However, when using PGRs, it is important to keep in mind that they can also have an effect on herbivores and parasitoids (Zhao et al., 2017). Thus, it is necessary to use them cautiously, especially when managing trees in urban landscapes (Moore, 1998). In order to effectively use PGRs as a tool for tree management, one must have a good understanding of their effects (Strydhorst et al., 2018). To put it simply, the application of PGRs can effectively reduce the frequency of mowing and maintain grain yield (Strydhorst et al., 2018).

2.2 Physiological and biochemical processes involved in the action of plant growth regulators

Atypical PGRs include spinosad, which acts as an allosteric inhibitor Nauen, Ralf & Bretschneider, Thomas. (2002). In other words, spinosad works by interfering with the process of mutation induction Kada, Tsuneo & Shimoi, Kayoko (1987). Therefore, it is important to distinguish between the primary and secondary stages of action when studying the mode of action of a disinfectant (Maris, 1995). As for the biochemical approaches to the mode of action, it has been revealed that trichothecenes are potent inhibitors of SH-group proteins and are thus related to the molecular mechanism of action (Ueno, 1978). Furthermore, it is possible to use a response profile for a compound with an unknown mode of action to deduce its potential mode of action (Duke, 2011). Serenade works through complex modes of action that involve the biological action of the bacteria and lipopeptide compounds (Marrone, 2002). Agents suppressing cellular mutagenesis have been known for some time, and their modes of action have been extensively studied (Kada et al., 1986). However, toxic mode of action of nanosilver is still not well understood as in vivo exposure studies have only recently been completed (Völker et al., 2012). Vaccines have also been studied in order to understand their modes of action since the early 20th century (Cox & Coulter, 1997). All of this evidence reveals the importance of studying the physiological and biochemical processes involved in the action of plant growth regulators.

2.3 Advantages and impact of using plant growth regulators for turfgrass management

Plant growth regulators are a useful tool for turf grass management. Synthetic compounds, such as the commercial cyclohexanedione class growth regulator, are developed to be used as anti-lodging agents in cereals, grasses, rice and as a growth regulator for turf (Faria et al., 2015). The availability of sophisticated methods for the identification and quantitative measurements of PGRs, hormone mutants, and powerful tools of molecular biology has further improved the use of PGRs as a management tool (Basra, 2000). Plant growth is regulated by the interaction of environmental factors and intra-plant hormone levels (Reddy et al., 1995). Class II growth regulators suppress grass growth through interference of gibberellin biosynthesis and can be used to manipulate plant growth (Watschke et al., 2015). However, caution should be exercised when using PGRs, as they can have unintended consequences for the growth of plants, as well as herbivores and parasitoids (Zhao et al., 2017). PGRs can be used as a risk management tool to produce shorter stems, reduce lodging, and maintain grain yield (Strydhorst et al., 2018). Therefore, an understanding of PGRs can help to effectively manage trees in urban landscapes (Moore, 1998). The application of plant growth regulators is an effective way to reduce stress and improve the health and quality of turf grass. In this research, GA synthesis inhibitor products such as Anuew™ and Muskateer® were used due to their longer efficacy during high-temperature periods (Drake, et al.,2023). Anuew™, which has prohexadione calcium as the active ingredient,was found to be more effective than trinexapac-ethyl (Drake, et al., 2023), which is widely used on golf course turf. The application of AVG was found to be effective at low rates, with the potential to be used as an emergency application. However, the cost of approximately $260/ha would not be unreasonable for many golf courses. It is also important to note that the response of turf grass to stress may not be sufficient even with the application of PGRs (Drake, et al., 2023). Plant growth regulators can also alter phytohormone levels in turf grass,which can lead to discoloration, weakening, and reduced tolerance to traffic. In addition, GA synthesis inhibitors such as trinexapac-ethyl, triazoles, and prohexadione calcium can increase cytokinin levels in turf grass,resulting in improved plant health during stress periods (Drake, et al., 2023). 2,4-D can also promote healthy rooting and enhance turfgrass health,though it was found to be slightly harmful during the experiment. It is recommended that products containing 2,4-D should not be applied when temperatures reach ~30 °C,as increased electrolyte leakage may occur. In conclusion, although sequential applications are typically required to generate plant health benefits, the application of PGRs can result in darker green turfgrass, increased stress tolerance, and overall superior turfgrass quality (Drake et al., 20023).Plant growth regulators have been used for many years to manage turf grass, with the goal of achieving the best visual score (Głąb et al., 2020). Their effects have been tested on a variety of grass species, such as Poa pratensis L. and creeping bentgrass (Watschke et al., 2015), and their utilization brings about a decreased need for excess nitrogen application (Zhang, 2016). It appears that the effects of different doses of PGRs vary depending on the species of grass (Roberts, et al., 2016)), and that the application of PGRs during periods of stress can be beneficial for turf health (PGR Effects on Turf under Heat and Salt Stress - GCMOnline.com, n.d.) (Drake et al, 2023). Studies have also looked at the effects of PGRs on Poast and Oust, which are used as growth retarders and seedhead suppressors of grasses (Wells, 1989), and have examined how the root mass and quality of turf stands are affected by turf paints (Long, 2006). Furthermore, the most widely used plant growth regulator is 2,4-Dichlorophenoxyacetic acid (Nickell, 1994), which has the potential to improve fruit quality if used correctly. It has also been suggested that the exogenous application of PGRs can alleviate the negative effects of high temperatures (Fahad et al., 2016), and research has shown that a two-fold increase in α-tocopherol can be observed under drought conditions when PGRs are used. In conclusion, PGRs can be a useful tool for managing turf grass and reducing the need for excess nitrogen if utilized with caution.

2.4 Benefits of using plant growth regulators to manage turfgrass

Plant growth regulators are synthetic compounds that are widely used to manage turf grass in lawns, golf courses, parks, cemeteries, and highways (Nickell, 1994). PGRs are used to produce shorter stems, reduce lodging, and maintain grain yield (Fahad et al., 2016). They have been found to reduce the negative effects of high temperatures on plant growth (Fahad et al., 2016). It has been observed that a two-fold increase in α-tocopherol occurs under drought stress when PGRs are used (Fahad et al., 2016). Additionally, the use of PGRs can improve turf quality (Watschke et al., 2015). For example, the application of PGRs such as trinexapac-ethyl has been found to generate the best visual score (Roberts, J. A., Ritchie, D. F., & Kerns, J. P. 2016)), allowing an objective assessment of turfgrass quality without the error of subjective assessment (Głąb et al., 2020). As a result, PGRs can be used as a risk management tool (Głąb et al., 2020). However, it has been found that PGRs can have different effects based on the grass species (Zhang, 2016), and should be used cautiously to regulate plant growth (Fahad et al., 2016). Furthermore, applying PGRs to turfgrass areas has been found to delay quality loss (Watschke et al., 2015), while excess nitrogen application results in increased disease occurrence and poor turf quality (Zhang, 2016). Moreover, PGRs can be used to improve grass health, and thus promote high-quality healthy turf (PGR Effects on Turf under Heat and Salt Stress - GCMOnline.com, n.d.) (Drake, A. M., Petrella, D. P., Blakeslee, J. J., Danneberger, T. K., & Gardner, D. S. 2023).

Finally, PGRs such as Poast and Oust have been found to act as a growth retarder and seedhead suppressor of grasses (Wells, 1989), as well as improve the root mass and quality of the turf stand (Long, 2006). Plant growth regulators are widely used in modern agriculture, horticulture, and turfgrass management (Baldwin et al., 2009). The objectives of this study were to investigate the effects of two PGRs (Elansary & Yessoufou, 2015), and their efficacy for clipping reduction (Long, 2006). Plant growth regulators have a profound impact on turfgrass management (Long, 2006) and are essential for successful turfgrass culture (Baldwin2009), as they increase the efficacy of fungicides (*Plant Disease 1996 | Interactive Effects of Plant Growth Regulators and Fungicides. On Epidemics of Dollar Spot in Creeping Bentgrass*, n.d.) and improve turf in shaded conditions Steinke, Kurt & Stier, J.. (2003). Further research is needed to investigate if greater drought tolerance of subsurface drip-irrigated turf is the result of increased water-use efficiency due to altered root morphology (Schiavon et al., 2014). Reviews of growth regulation in turfgrass science (Watschke et al., 2015) have found that the application of certain PGRs may have increased the efficacy of fungicides (*Plant Disease 1996 | Interactive Effects of Plant Growth Regulators and Fungicides. On Epidemics of Dollar Spot in Creeping Bentgrass*, n.d.) and better efficiency of photosynthesis (Elansary & Yessoufou, 2015). However, current methods for detection of these herbicides can cause damage to plants, leading to PGRs interfering directly with the plant's hormonal status and affecting the growth and flower production in flowering crops (March et al., 2013). The effects of PGRs and herbicides on *Poa annua* biotype turf quality (Williams, 2014) and Michigan roadside turfgrass Steinke, Kurt & Stier, J.. (2003) were also studied in order to provide a better understanding of the potential risks of using PGRs in turf management practices.

3 CHARACTERISTICS OF POA ANNUA

Poa annua L. is a species with 2n=28 chromosomes, making it an allotetraploid (Tutin, 1952). This hypothesis is supported by its morphological traits; for instance, annual *Poa annua* plants have lower leaf and node numbers, secondary tiller numbers, and adventitious root numbers than perennial plants (Gibeault, n.d. 1970). Furthermore, annual *Poa annua* plants reach reproductive maturity quicker than perennial plants (Gibeault, n.d. (1970)). Perennial *Poa annua* plants are mostly found in areas that receive moderate or intensive supplemental irrigation. Studies conducted in the Northern Pacific Coastal regions of Oregon and Western Washington showed that of the samples collected from turfed areas, over 50 percent exhibited perennial characteristics, and both types were evenly distributed (Gibeault, n.d. 1970). The diploid parents of *Poa annua P. infirma* H. B. K. and *P. supina* Schrad. both have 2n=14 chromosomes (Tutin, 1952). Open pollinations have failed to produce viable hybrids between the two, further supporting the allotetraploid hypothesis (Tutin, 1952). *Poa annua* has also been studied for its level of polymorphism, genetic variability and relatedness (Chwedorzewska, 2007).*Poa annua* is a versatile species of grass, with both annual and perennial biotypes, which can be identified by their morphological characteristics and seed germination requirements (Chwedorzewska et al., 2015; Gibeault, n.d. 1970). Carl von Linné classified it in 1753, and since then nearly 50 taxa of *P. annua* have been identified (Carroll et al., 2021). It is also known as annual meadow grass, and is commonly used in turfgrass systems (Jr & Turgeon, 2003). *Poa annua* is a relatively new species that is believed to have originated from two diploid parents, *Poa infirma* and *Poa supina* (Mao & Huff, 2012; Tutin, 1952). It is also found in various urban environments, where it can spread through the interstices between paving (Hutchinson & Seymour, 1982). It is an allotetraploid and is widely spread through vectors (Chwedorzewska, 2007). In addition, it has been observed that the presence of *Poa annua* can increase the performance of other plant species, as seedling numbers in the following generation were four to six times as high for Capsella and Senecio when *Poa annua* was present (Bergelson, 1990). Therefore, it is clear that *Poa annua* is an important species that has a significant impact on its environment.

3.1 Impact of *Poa annua* on turf grass management

Annual Meadow Grass, or *Poa annua*, is a species of grass with both annual and perennial populations (Law et al., 1977; Chwedorzewska et al., 2015). It was first classified by Carl von Linné in 1753, and nearly fifty taxa of P. annua have been identified since (Carroll et al., 2021). This species is often written as *Poa annua*, and is commonly found in turfgrass systems, either as a weed or a desirable species (Jr & Turgeon, 2003). *Poa annua* is believed to be recent on an evolutionary time scale, and its diploid parents are Poa infirma HBK and *Poa supina* Schrad (Mao & Huff, 2012). This species is also found in various urban settings, such as between paving stones (Hutchinson & Seymour, 1982). Through experimentation, it has been discovered that seedling numbers in the following generation are four to six times as high for Capsella and Senecio when *Poa annua* is present (Bergelson, 1990). Furthermore, genetic variability and relatedness of a population of *Poa annua* L. from South Shetlands has been studied (Chwedorzewska, 2007). It is believed that this species is spread by many different vectors (Chwedorzewska, 2007), and it is clear that *Poa annua* can have a significant impact on turf grass management (Gibeault, n.d.1970; (Tutin, 1952).

3.2 Plant growth regulators used in *Poa annua*

Plant growth regulators are chemical compounds used to control the growth of plants. In *Poa annua*, these chemicals are used to suppress seedheads, and studies have shown that multiple applications of low rates of these chemicals can result in better seedhead inhibition (Askew, 2017). Paclobutrazol and flurprimidol are the two PGRs most commonly used in *Poa annua* (Johnson & Murphy, 1995; McCullough et al., 2013), and research has indicated that paclobutrazol applied at 0.3 or 0.6 kg/ha can suppress *P. annua* spp. reptans 28% 4 months after the final treatment (Johnson & Murphy, 1995). The same study also revealed that flurprimidol applied four times during each of 2 years suppressed *P. annua* spp.

reptans 22 to 27% 1 month after the final treatment (Johnson & Murphy, 1995), but the suppression rate declined to 7% 4 months after the final treatment. Additionally, ethephon and trinexapac-ethyl are used in a spring, two-treatment program to suppress annual bluegrass seedheads on golf greens, while mefluidide is another PGR that can be used (Askew, 2017b). All PGRs reduce the number of seeds produced and have an effect on the number of seeds that germinate from soil taken from treated plots, however, endothall, especially the granular formulation, can cause excessive injury (Askew, 2017). Furthermore, an early application of ethephon in January or February prior to the spring treatment program can result in significantly less seedhead cover with minimal injury to creeping bentgrass and only slight and transient discoloration to annual bluegrass (Askew, 2017b). Lastly, three spring and three fall applications of paclobutrazol and flurprimidol suppressed the perennial subspecies of *Poa annua* ≥ 72% and 22 to 27% respectively, 3 weeks after the final treatment, and did not injure creeping bentgrass when applied in November (McCullough et al., 2013).

3.3 Effect of PGR on the formation of seed heads in *Poa annua*

Plant growth regulators have been studied to discover their effects on Poa annua suppression in turfgrass. While herbicides have been used to control the weed, they have been found to be unpredictable McCullough, P. E., Hart, S. E., & Lycan, D. W. (2005). Therefore, PGRs are being employed to reduce *Poa annua* seedhead formation (Askew, 2017; Askew, 2017b) Jackson, I., O'connor, B., Jacobson, D.,1986. Studies have demonstrated that treatment with paclobutrazol at 0.3 kg/ha in four applications during the same period suppressed *P. annua* spp. (Johnson & Murphy, 1995), while an early application of ethephon in January or February prior to the spring treatment program has resulted in significantly less seedhead cover McMahon, G. and Hunter, A. (2012). Surveys have also revealed that PGRs are the most common response to *Poa annua* control (Williams, 2014). Additionally, mefluidide at 0-1.2 kg/ha has been found to affect the growth of Agrostis stolonifera and *Poa annua* (Brown, 2013), while paclobutrazol and flurprimidol were evaluated for suppression of *Poa annua* (McCullough et al., 2013). Plant growth regulators have been shown to reduce *Poa annua* populations in creeping bentgrass (Haguewood, 2014), and their impacts on the weed have been observed at different growth stages McMahon, and Hunter, 2012). Ultimately, PGRs provide a viable solution to *Poa annua* suppression in turfgrass. Plant growth regulator regimens have been shown to reduce *Poa annua* populations in creeping bentgrass (Haguewood, 2014). Plant growth regulators paclobutrazol and flurprimidol were evaluated for suppression of *Poa annua* (Johnson & Murphy, 1995). In recent years, PGRs such as paclobutrazol and tlurprilnidol have been evaluated for the control of the perennial subspecies (McCullough et al., 2013). The effect of mefluidide at 0-1.2 kg/ha on perennial ryegrass, browntop, sweet vernal grass, *Poa annua*, Hordeum spp. and on road verges and parkland were studied Jackson, I., O'connor, B., Jacobson, D.,1986. To determine the degree to which annual bluegrass could be controlled, research was conducted to analyze the effects of these materials on pollen quality and the viability of seed produced by treated plants (Askew, 2017). 72 golf course superintendents or workers were asked to provide their opinion on the best method to control *Poa annua* and PGRs was the most frequent response (Williams, 2014). Herbicides and PGRs are often used for ABG control, providing limited or erratic control between years and locations (Brown, 2013). Plant growth regulators, such as trinexapac-ethyl (moddus and primo maxx) and mefluidide (embark lite), affected the growth of Agrostis stolonifera and *Poa annua* significantly and the numbers of *Poa annua* were reduced 4 months after treatment (McMahon and Hunter, 2012). Thus, PGRs have been considered effective in controlling the seed head formation of *Poa annua.*

3.4 Methods to assess the effects of plant growth regulators on *Poa annua*

Plant growth regulators are artificial molecules that can be used to control plant growth, and are particularly useful when it comes to vegetables and fruits (Helmy et al., 2015). Different concentrations of these compounds, such as IAA, NAA and GA 3, were evaluated in a study conducted in India (Verma et al., 2008), and the effects of their application on plant growth were also assessed (Lin et al, 2021). Further, the concentration of synthetic PGRs residues, as well as their environmental effects, were studied (Bamberger, 1971). Also, the influence of different PGRs on yield-forming parameters, seed yield and oil content were examined (ERNST et al., 2016). Similarly, the fungistatic effect of demethylation inhibitors (DMIs) and PGRs was also assessed (Ok et al., 2011). Lastly, the potential influence of three soil additives on plant growth was evaluated (Subler et al., 1998). All of these studies demonstrate that PGRs can have a significant effect on plant growth when used in the right concentration and setting (Stover & Greene, 2005). Furthermore, it is also evident that PGRs can be used in a variety of applications, such as modulating plant growth or controlling the effects of environmental factors (Rodriguez-Furlán et al., 2016).Research has been conducted to determine the effectiveness of PGRs in various regions across the globe Verma, Piyush & Sen, N.. (2008). This has been done in an effort to reduce the negative effects of herbicides on the environment (Lin, et al., 2021). It has been found that high concentrations of the small molecules of the PGRs are necessary to achieve a desired effect (Bamberger, 1971). PGRs for vegetables and fruits have become more popular in recent times (Helmy et al., 2015), and their effect is usually assessed by measuring the environmental impact of the PGR (Stover & Greene, 2005). The application of PGRs has long been used to regulate plant growth (Rodriguez-Furlán et al., 2016). Studies have been conducted to assess the concentration of synthetic PGR residues (ERNST et al., 2016), and to evaluate the sensitivity of certain plants to multiple PGR treatments (Ok et al., 2011). Additionally, some soil additives have been found to have a direct influence on plant growth (Subler et al, 1998). PGRs have become an effective method of suppressing seedheads in *Poa annua*,and applications of paclobutrazol and ethephon have been known to reduce seedhead cover (Verma et al., 2008). However, the application of PGRs must be carefully monitored, as there is potential for both positive and negative effects on the environment. To accurately measure and evaluate the effects of PGRs, numerous studies have been conducted in the past. For instance, Breuninger (2) found that PGRs had varied effects on plant growth depending on the growth stage (Lin et al., 2021). Similarly, the application of PGRs can be used to suppress the growth and production of *Poa annua*, an invasive weedy species in turfgrass Verma, Piyush & Sen, N.. (2008), as selective herbicides provide inconsistent control (Subler et al, 1998). However, the required concentrations of the small PGR molecules to achieve the desired effect are high (Bamberger, 1971), and the effects of PGRs on plant growth have not been widely studied (Helmy et al., 2015). As such, the objectives of the study conducted by Deng et al. (7) were to evaluate the effects of foliar application of two different PGRs on yield-forming parameters, seed yield and oil content (ERNST et al., 2016). Furthermore, the study of Imtiyaz et al. (8) aimed to assess the sensitivity of S. homoeocarpa to multiple doses of DMIs and PGRs (Ok et al., 2011). This study found that PGRs had a positive influence on plant growth, as evidenced by P-values that were lower than 0.05 for PGR/adjuvant treatment for almost every response variable (Stover & Greene, 2005), and three soil additives were found to have an effect on plant growth (Rodriguez-Furlán et al., 2016). Therefore, it is clear that PGRs play an important role in the growth of plants, and their effects must be carefully measured and evaluated.

4 Aim Of the experiment:

Plant growth regulators (PGRs) are chemicals used to modify plant growth such as increasing branching, suppressing shoot growth, increasing return bloom, removing excess fruit, or altering fruit maturity. An experiment to test the effectiveness of ATTRAXOR, which is a product of BASF-Italia, a chemical company that also specializes in plant products; it was carried out during 2023. We tested the influence of ATTRAXOR on the growth of *Lolium perenne /poa pratensis* and *poa annua* seed head formation. ATTRAXOR was compared with a PGR that is widely used for turfgrass management (Primo Max II). We evaluated the effect of PGRs on turf with parameters like turf colour, turf height, vertical growth rate of the vegetation using a plate meter. In case of *poa annua* plots the seed head formation and height of the inflorescence are also measured, and the local weather data were also collected.

4.1 Materials & Methods

The study was conducted at the Agricultural Experimental Farm of the University of Padua, located in Legnaro (45°20' N, 11°57' E; altitude 8 m above sea level). The region is characterized as having a humid sub-tropical climate (Köppen-Geiger climate classification system) with annual precipitation of 831 mm/year, mostly occurring from April to November, and an average annual temperature of 12.3°C (8.0 = minimum, 17.4 = maximum). The soil was coarse-silty, mixed,mesic, Oxyaquic Eutrudept, of a loam soil texture. Two experiments were conducted over a period of 2 years, comparing ATTRAXOR and Primo MAX II from March 2023 to March 2025. The experiment was conducted on *Lolium perenne /poa pratensis* turfgrass (Exp. 1) and on a monostand of *poa annua* (Exp. 2). The experimental design was a Randomized complete block with three replicates. The plot size of experiment 1 with *Lolium perenne /poa pratensis* was 4m × 2.5 m and the plot size of experiment 2 was 4m × 2.5 with *Poa annua* seeded in a 60cm × 60 cm test area. Throughout the experiment, a rotary mower machine was used to maintain turfgrass at 25 mm. Mowing frequency varied depending on the season. A weekly mowing was conducted for most of the growing season. Additionally, vertical mowing or aeration was considered, following appropriate methods and timing. Irrigation was carried out based on specific stages of the experiment. Before seedling emergence, irrigation was applied at a rate of 6-7 mm/day to ensure optimal moisture for germination. After seedling emergence, weekly irrigation was performed from June to August, and as necessary, in the other months, applying 30 mm of water. Weed control was carried out to manage both grassy and broadleaf weeds. Grassy weeds were controlled manually by hand, where they were identified and removed from the plots. For broadleaf weeds, a post-emergence herbicide treatment (Dicamba + Mecoprop) was conducted once, 40 days after sowing. After achieving full establishment, broadleaf weeds were manually removed by hand. The specific herbicide and application method should be chosen based on herbicide efficacy and safety guidelines

4.2 Climatic Characterization:

The *hot season* lasts for *3.2 months,* from *June 4 to September 10,* with an average daily high temperature above *25.5*°C. The hottest month of the year in Legnaro is *July*, with an average high of *30*°C and a low of *18.9*°C. The *cold season lasts for 3.2 months*, from *November 20* to *February 29,* with an average daily high temperature below *11.11*°C. The coldest month of the year in Legnaro is *January*, with an average low of *-0.5*°C and a high of *6.7*°C. A *wet day* is one with at least *0.04 inches* of liquid or liquid-equivalent precipitation. The chance of wet days in Legnaro varies throughout the year. The *wetter season* lasts *7.9 months*, from *March 25* to *November 21*, with a greater than *22%* chance of a given day being a wet day. The month with the most wet days in Legnaro is *June*, with an average of *8.5 days* with at least *0.04 inches* of precipitation. The *drier season* lasts *4.1 months*, from *November 21* to *March 25.* The month with the fewest wet days in Legnaro is *January,* with an average of *4.9 days* with at least *0.04 inches* of precipitation. The month with the most days of *rain alone* in Legnaro is *June*, with an average of *8.5 days*. Based on this categorization, the most common form of precipitation throughout the year is *rain alone*, with a peak probability of *30%* on *June 3* (Legnaro Climate, Weather by Month, Average Temperature (Italy) - Weather Spark, n.d.)..

4.3 Data Collection

Weather Data Collection at Legnaro Weather Station for the year 2023. The Legnaro Weather Station is located at 45°20' N, 11°57' E, an altitude of 10 m above sea level. The station serves as a vital data collection point for weather observations in the region. It is equipped with various instruments and equipment, including thermometers, barometers, anemometers, and rain gauges. The station infrastructure is regularly maintained and calibrated to ensure accurate and reliable data collection. Regarding experiment 1, the NDVI was utilized to assess the physiological status of the turfgrass. The RapidSCAN CS-45 Handheld Trim Sensor was utilized to perform one estimation per plot. This instrument gives a more dependable and objective assessment, complementing visual assessments that will be subject to all levels of subjectivity. The sensor assesses the light reflected by the clears out based on a known light beam. In the event that the plant is solid, it reflects within the near-infrared extent, whereas in the case it is focused, it reflects within the near-infrared extent, driving to a diminish within the NDVI value. One estimation per plot was taken every two weeks, coming about in an add to 27 estimations per week. The sensor isn't influenced by encompassing lighting, permitting precise biomass estimations during the day or night due to its inner polychromatic light source. The sensor can assemble information from vegetation at separations extending from 0.3 meters to over 3 meters. The data created by the sensor incorporates NDVI/NDRE (Normalized

Contrast Ruddy Edge) vegetation records, latitude/longitude, and test measurements, as well as essential reflection data. The RapidSCAN CS-45 sensor joins three optical estimation channels, at the same time measuring crop/soil reflectance at 670 nm, 730 nm, and 780 nm. A special highlight of the RapidSCAN CS-45 sensor is its capacity to perform tallness-free ghastly reflectance estimations. Holland Logical alludes to these reflectance estimations as pseudo sun based reflectance (PSR) estimations. As such, the ghostly reflectance groups are rescaled into rates and do not shift with the sensor tallness over a target. The aesthetic aspect evaluation involved visual assessments of texture, uniformity, density, colour, and overall aesthetic appearance. Each layout received a score ranging from 1–9, with 6 suggesting sufficient (Morris and Shearman, 1998). The texture of leaf blades varies by species and type. Uniformity measures the uniformity of the grass. Species, environmental factors, and cultural practices all have a significant impact on density, which estimates tillering. Colour is examined, with darker varieties receiving higher ratings. The aesthetic look includes all of the aforementioned elements. Regarding experiment 2. The number of *Poa annua* seedheads was weekly counted in the field from the first seedhead emergence and the height of each seedhead was measured.

4.4 Statistical Analysis

All the collected data were subsequently subjected to analysis of variance using R software (R Development Core Team, 2021). For parameters such as turfgrass color, overall aesthetic appearance, and NDVI, *P. annua* seedhead number and height, the analysis of variance was performed using a mixed-effects linear model to test the effects of 'Treatment,' 'Measurement date,' and their interaction. For the parameters clippings dry weight and vertical growth ratethe analysis of variance was performed using a linear model to test the 'Treatment' effect only. The models were executed for each measurement.

Fig1. Measurement of the height of the turfgrass before mowing using grass plate meter.

Fig 2. Counting of germination of *Poa annua* seeds.

Fig.3. Visual estimation of turf color and turf quality.

Fig.4. Measurement of the height of the *Poa annua* inflorescences.

5.Results & Discussion

5.1 Weather Data

The weather data were analysed by using Excel software. The fluctuation of temperatures and precipitations at the experimental location was investigated from January 2023 to December 2023. The average temperature for January 2023 was recoded 6.24℃ indicating a cold condition at the beginning of the observation period. From February 2023 onwards, there was a gradual increase in temperature, ultimately reaching a level of 17.8℃ in May 2023. This rise in temperature suggests a transition towards milder conditions as spring approached. During June, July and august the temperature start to rise and reaches 24.8℃ in July which is peak of the season and from august 2023 the temperature starts to fall and reaches an average of 5.4℃ in December. Fig.5 illustrates the temporal pattern of temperature variations throughout the study period, depicting the observed fluctuations.

Regarding precipitation, the total value for January 2023 was 57.8mm, indicating a moderate level of rainfall during that month. Notably, the months of April, May, July, August, October and November exhibited a total precipitation range between 70mm and 170mm, suggesting consistent levels of rainfall during those periods maxing out during moth of may adding up to 169.2mm total rainfall. This indicates a notable increase in rainfall during that month, potentially influencing the local ecosystem and experimental conditions. The precipitation trends are visually represented in the form of a graph, providing a clear visualization of the observed patterns fig.5

These findings regarding temperature and precipitation fluctuations are crucial in understanding the environmental conditions under which the experimental study was conducted. They provide valuable insights into the potential influence of climatic factors on the experimental outcomes and contribute to the comprehensive analysis presented in this thesis.

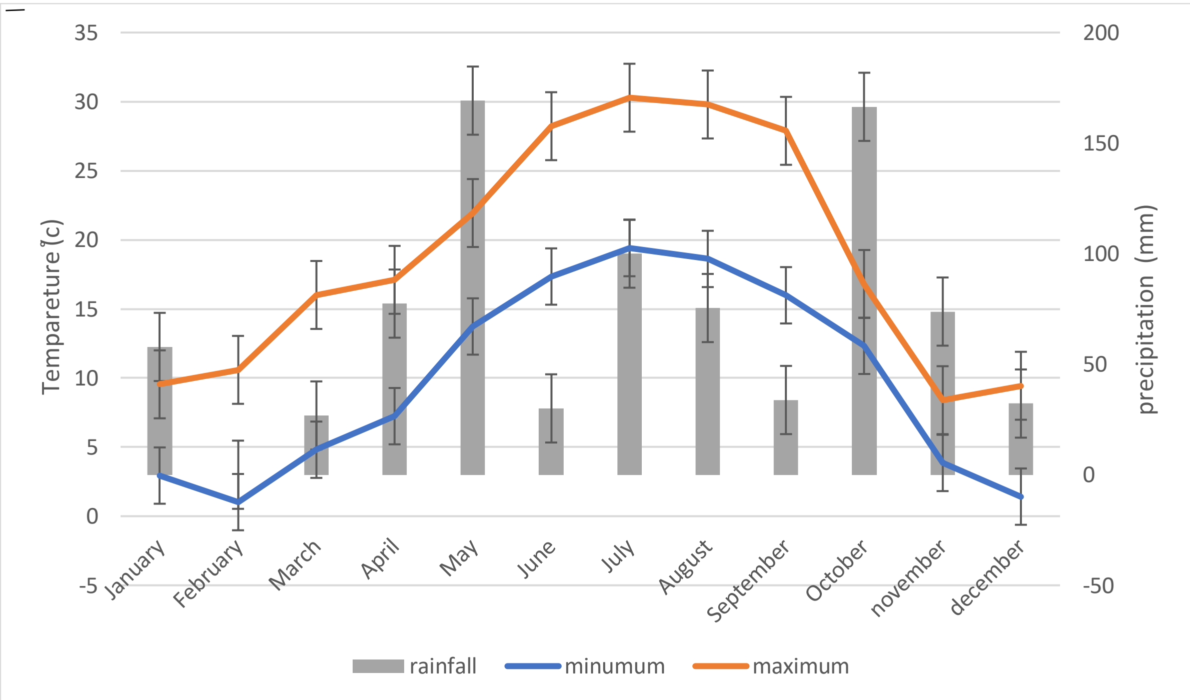


Fig.5. Precipitations and minimum and maximum temperatures in Legnaro (Italy) during 2023.

Table 1 reports the results of the analysis of variance (ANOVA) regarding the following parameters: turfgrass quality, color, NDVI, clippings dry weight, and vertical growth rate of a *L. perenne*/*P. pratensis* mixture subjected to PGRs applications. For Turf quality and NDVI, we found significant differences in 'treatment,' 'date,' and interaction 'treatment x date' effects. A significant 'treatment' effect was found for Clippings dry weight, NDVI, and Vertical growth rate.

Table 1. Results of ANOVA for the parameters Turfgrass quality, Color, NDVI, Clippings dry weight, and Vertical growth rate.

Source of variation	Overall turf quality	Turf color	NDVI	Clippings dry weight	Vertical growth rate
treat.	NS	NS	***	***	***
date	***	***	**	–	–
treat x date	**	*	(*)	–	–

Significance levels: (*) $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

NS: Not significant at the 0.1 probability level.

5.2 Turf Colour

The result indicates that the treatments has a significant effect as evidenced by the statistical analysis showing a significance level of $p < 0.01$ for the interaction treatment x date (Table 1). In the 1st month during the establishment stage there is a gradual increase in the turfgrass colour of the plots of ATTRAXOR, Control and Primo Maxx II (Fig. 6). During the months of June due to rise in temperature the turf colour stats on a downhill moment but starts to regain its colour during month of August as temperature starts falling, during September due to powdery mildew disease in the turfgrass plots there is a significant decrease in the turf colour post recovery from the disease the plots regained its natural momentum.

The statistical analysis revealed that the treatment effect was not significant (Table 1.). The results of ANOVA also revealed the significant effect of dates on the colour of the three different test blocks. The decline in colour observed in summer is likely attributed to the climatic conditions prevalent in the region during that period as this species enter dormancy when soil temperatures are higher.

Furthermore, a decrease in colour intensity occurred from July 2023 till August 2023 and from September 2023 till October 2023. This prolonged period of reduced colour can be attributed to the combination of low temperatures and limited sunlight exposure during the summer months and due to a disease, inhibiting the growth and pigment production. Subsequently, a considerable increase in colour intensity was observed, indicating the recovery after the summer period. Different regions may experience variations in temperature, sunlight exposure, and other climatic factors, which can influence the colour and overall health. These findings contribute to the understanding the effect of different growth regulators on turf colour.

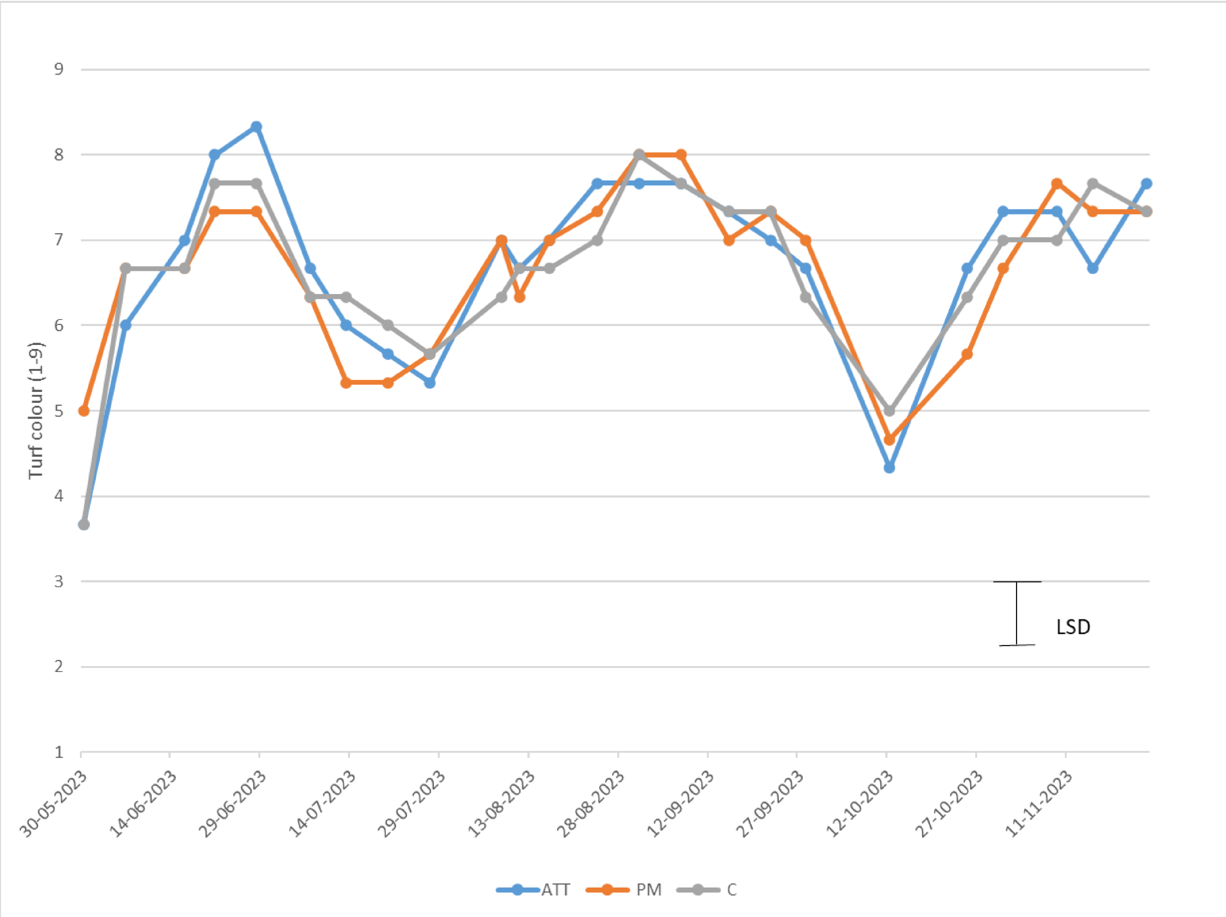


Fig.6. Turf colour in response to different growth regulators during the experimental period. (ATT = Attraxor, PM = Primo Maxx II, and C = control).

5.3 Turf Quality

Statistical analysis showed a significant interaction between treatment and dates ($p < 0.05$) . In the 1st month during the establishment stage, there is a gradual increase in the turfgrass quality of the plots of ATTRAXOR, Control and Primo Maxx II. During the months of June due to rising in temperature the turf quality started on a downhill moment but regain its quality during August as temperature starts falling, during September due to powdery mildew disease in the turfgrass plots the quality of the turf got compromised a lot but soon after recovery, it started to gain back its previous quality and growth was normalized.

The results of ANOVA also revealed the significant date effect. This demonstrated there is a significant seasonal variations in quality. This variation in quality is likely attributed to the climatic conditions prevalent in the region during that experimental period as this species enter dormancy when soil temperatures are higher. Or sudden change in the microclimate of the area.

Furthermore, results shown the lowest quality from July 2023 till August 2023 and September 2023 till October 2023. This prolonged period of reduced quality can be attributed to the combination of high temperatures and sunlight exposure during the summer months and due to powdery mildew(*Podosphaera xanthii*) inhibiting the growth. Subsequently, a considerable increase in quality was observed, indicating the recovery after the summer period. Different regions may experience variations in temperature, sunlight exposure, and other climatic factors, which can influence the quality and overall health. These findings contribute to the understanding the effect of different growth regulators on turf quality.

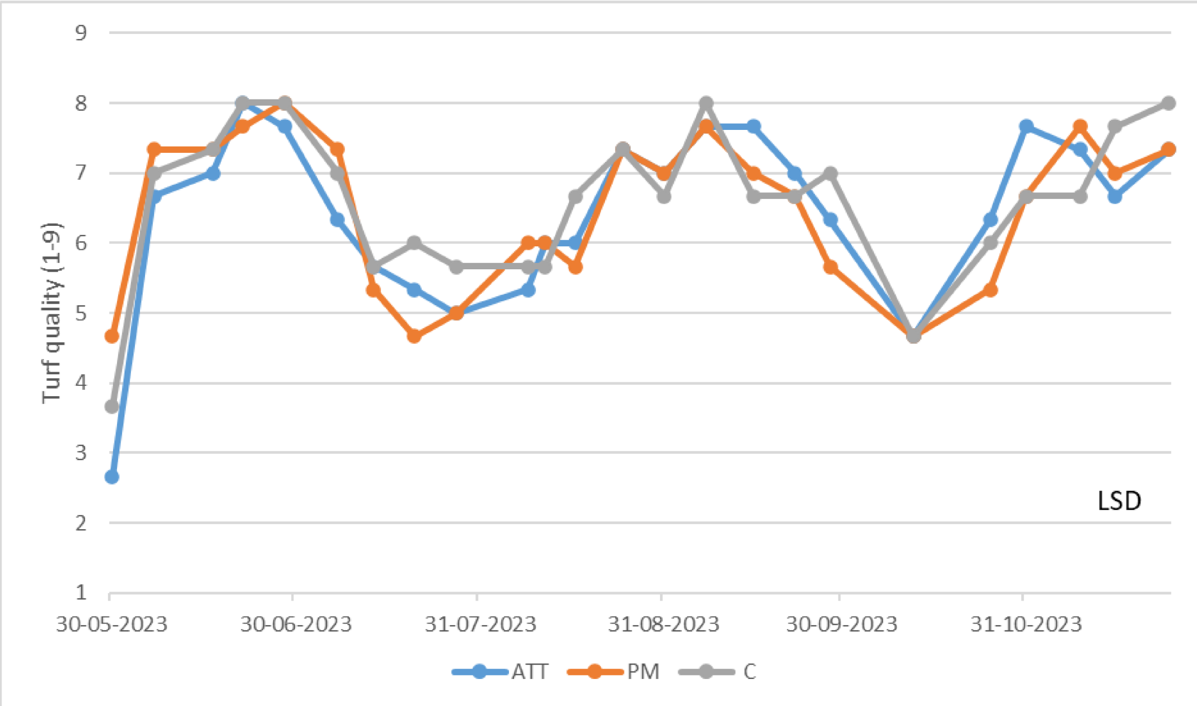


Fig.7. Turfgrass quality in response to different growth regulators during the experimental period. (ATT = Attraxor, PM = Primo Maxx II, and C = control).

5.4 NDVI

The statistical analysis revealed that three PGR have a significant effect on the NDVI at a significance level of $p < 0.001$ (Table 1). Additionally, the interaction between treatment and dates showed a significant effect on the NDVI at significance level of $p < 0.1$ (Table 1). The significant effect of treatment suggests a different response to PGR. The observed differences in NDVI among the PGRs may be attributed to genetic variations, which can affect factors such as chlorophyll content, leaf area, and photosynthetic efficiency. The findings suggest that different PGRs can exhibit variations in their vegetative growth and response to specific treatments. These results contribute to our understanding of how the ATTAXOR and Primo Maxx II perform in the real-world scenario. We can get a better understanding of the NDVI from the figure 8.

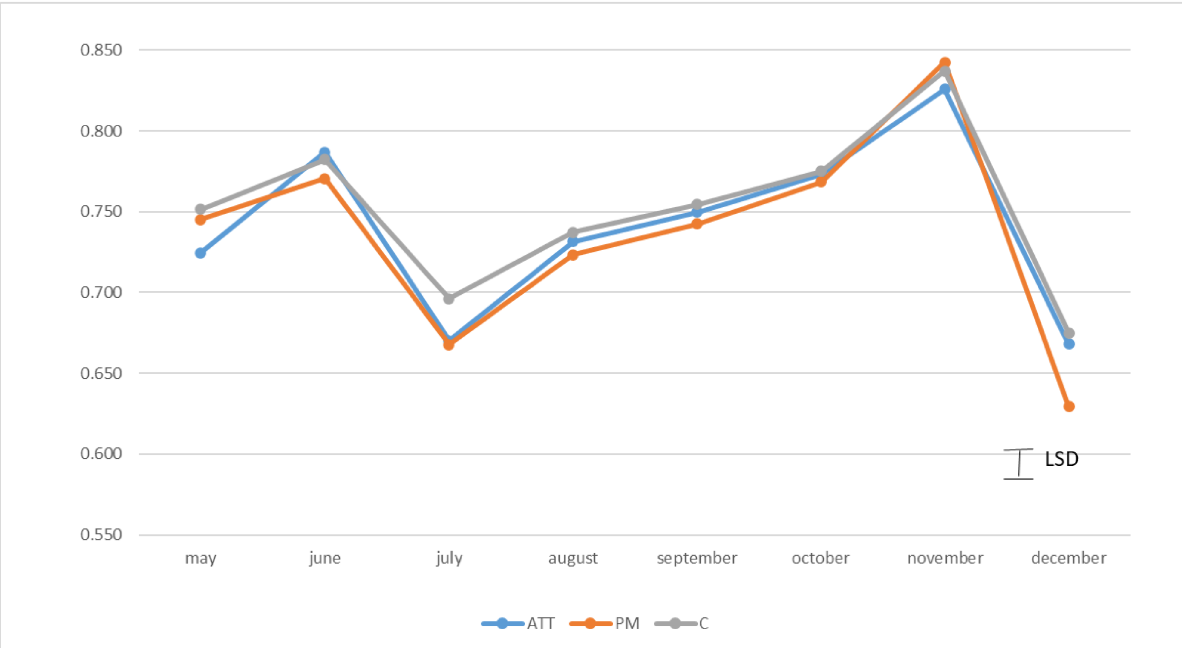


Fig.8. Index NDVI in response to different PGRs during the experimental period. (ATT = Attraxor, PM = Primo Maxx II, and C = control).

5.5 Vertical growth rate

The curves reported in (Figure 09) represent the cumulative growth of the turfgrass over the period of time from establishment till the last mowing. Here, the mowing is done on a weekly basis depending upon the weather conditions, so the time may vary by ± 1 day. It is calculated to get an average daily growth through which we can estimate an average daily growth and estimate if our product is showing its effect or not. This is calculated by first averaging out the height of the turf before mowing and then it is subtracted from the average cutting height, which is approximately 6.27cm and then the difference in height is added to get the cumulative growth.

The results of the analysis of variance showed a significant treatment effect ($P<0.01$). In (Figure 10) we can see the exact daily growth rate of the three turf plots with different PGRs and Control. Control having highest daily growth rate 0.20 cm/day followed by Primo Maxx II, 0.18 cm/day and with least growth rate of 0.17 cm/day of the ATTRAXOR.

The findings of this study have practical implications for this trial. Understanding the growth patterns and parameters helps in understanding whether the desired plant growth regulator can help turfgrass professionals and landscapers in selecting the most suitable plant growth regulator in reducing the growth and thus reducing the mowing frequency saving time money. The growth curve provides an insight to how much biomass does the specific grass produce in relation to the specific growth regulator. This helps in determining how much cost one can save in mowing operations as well as labour and thus provides a valuable insight. In the figure 10, below we can see clearly the growth curve of the three test plots using different plant growth.

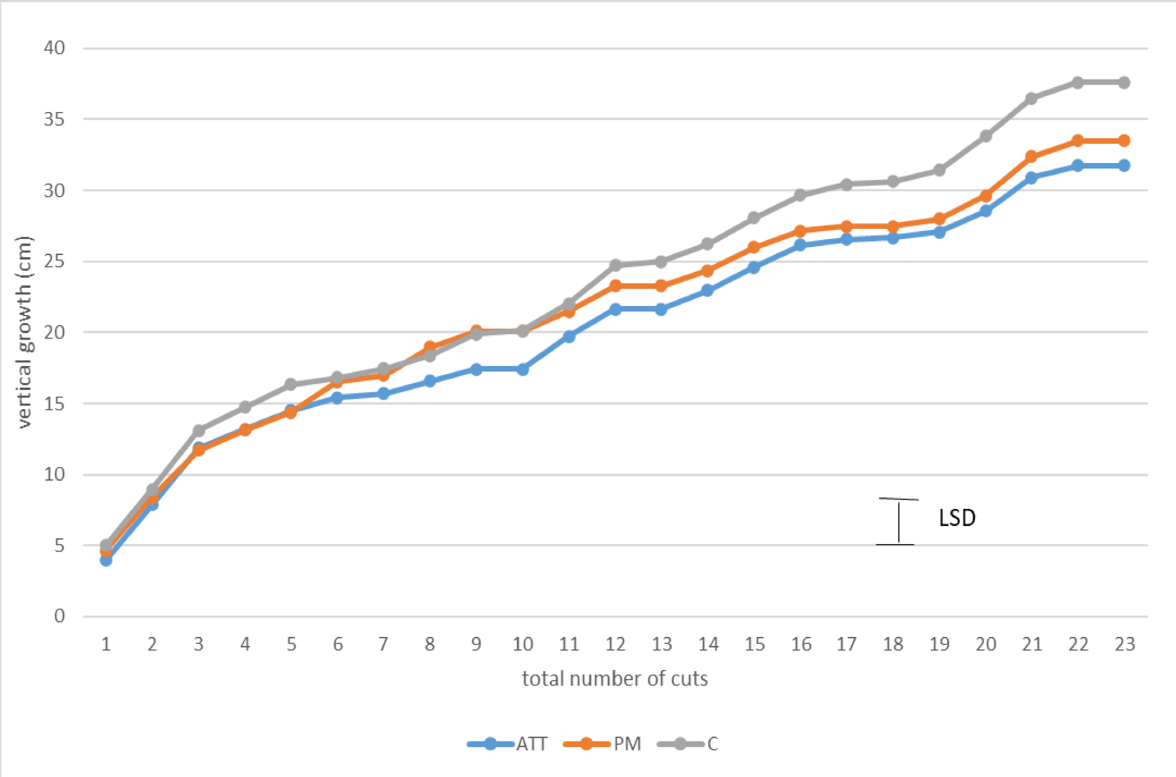


Fig.9 Cumulative vertical growth of the turfgrass using the three plant growth regulators (ATT = Attraxor, PM = Primo Maxx II, and C = control).

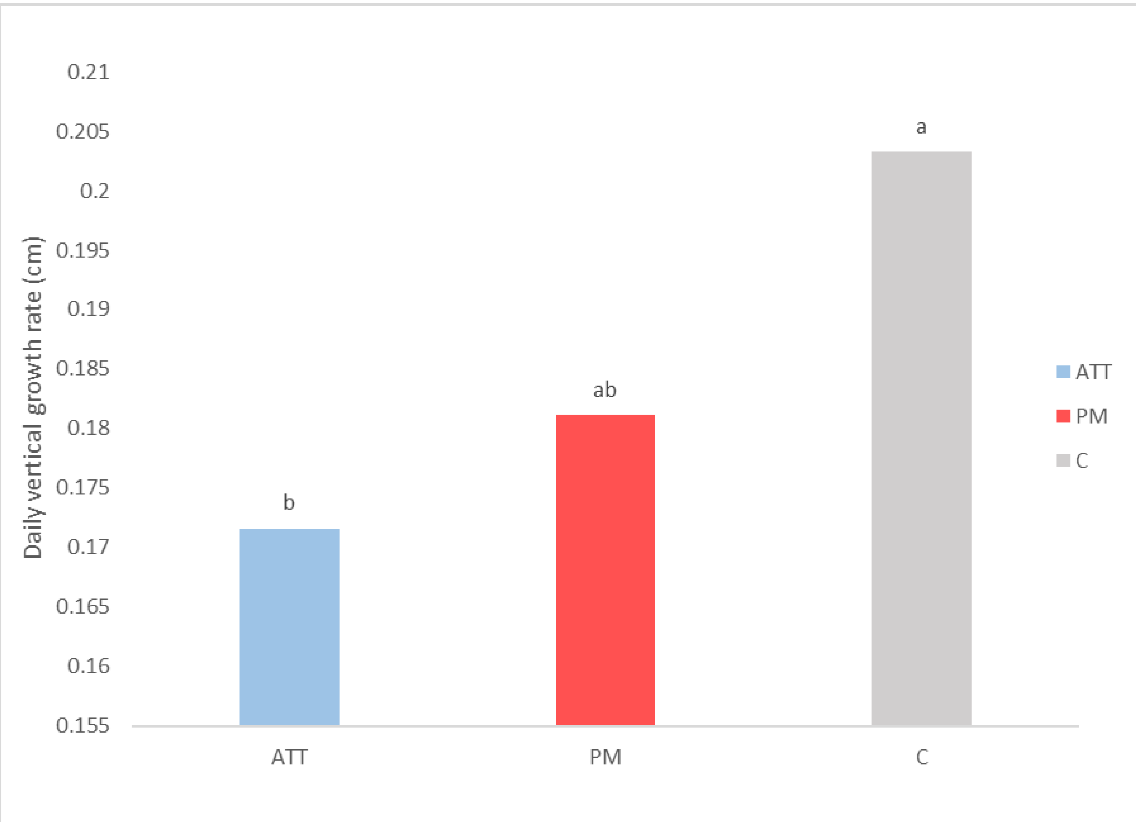


Fig.10 Average daily growth of turfgrass subjected to different PGRs (ATT = Attraxor, PM = Primo Maxx II, C = Control).

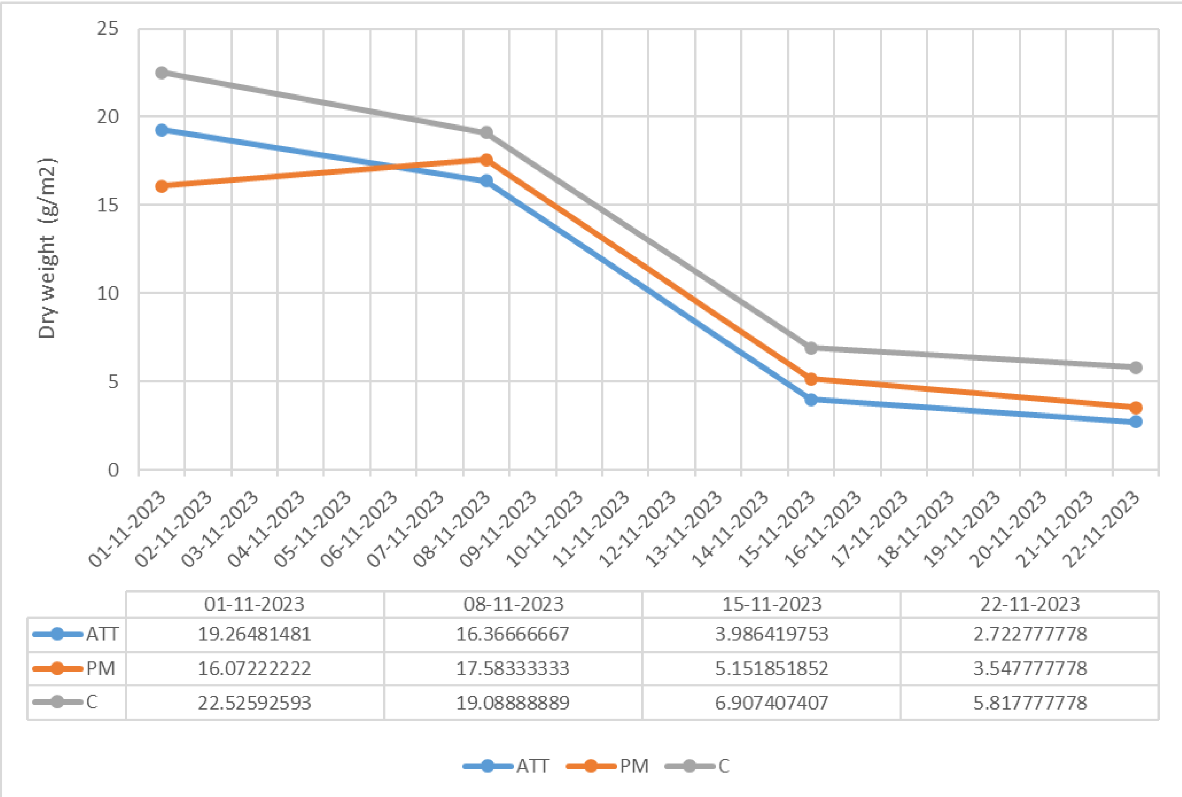
5.6 Clippings dry mass

From figure 12 we can observe that the clippings biomass measured in the fall period decreased over time. Differences among PGRs occurred in each cut with control having the highest dry weight followed by the Prim Maxx II which performed well initially in the 1st cut but later in comparison to ATTRAXOR did not perform well. ATTRAXOR, initially in the 1st cut produced more clippings dry weight than the subsequent cuts, later, from the 2nd cut onwards, it started to outperform the Primo Maxx II and produced less amount of biomass. In Figure we can observe the cumulative clippings dry weight deriving from the four cuts. The control produced the highest cumulative biomass. We can also observe that, initially, the ATTRAXOR and Primo Maxx II were producing less and more simultaneously, but during the final cut, it was observed that the cumulative dry mass was nearly equal, thus giving us a positive direction on the trial.

Since plants have a high composition of water and the level of water in a plant will depend on the amount of water in its environment (which is very difficult to control), using dry weight as a measure of plant growth tends to be more reliable. Dry weight will provide a precise measurement of biomass eliminating fluctuations caused by water content. Plant total biomass can be directly related to our plant performance as a response to photosynthetic capacity, nutrition, environmental conditions, and more.

To measure the dry weight we followed the following steps:

1. Cut the turf, we used a cylindrical mower and cut the grass.
2. The clippings are collected and tagged
3. Wet weights are taken
4. The clippings were put on aluminum plates and were put inside the hot air oven for 48 hours at 100 degrees centigrade.
5. After 48 hours, the clippings were removed, and the dry weight is measured.



	01-11-2023	08-11-2023	15-11-2023	22-11-2023
ATT	19.26481481	16.36666667	3.986419753	2.722777778
PM	16.07222222	17.58333333	5.151851852	3.547777778
C	22.52592593	19.08888889	6.907407407	5.817777778

Fig.11. Clipping dry mass at four autumn cuts (ATT = Attraxor, PM = Primo Maxx II, C = Control).

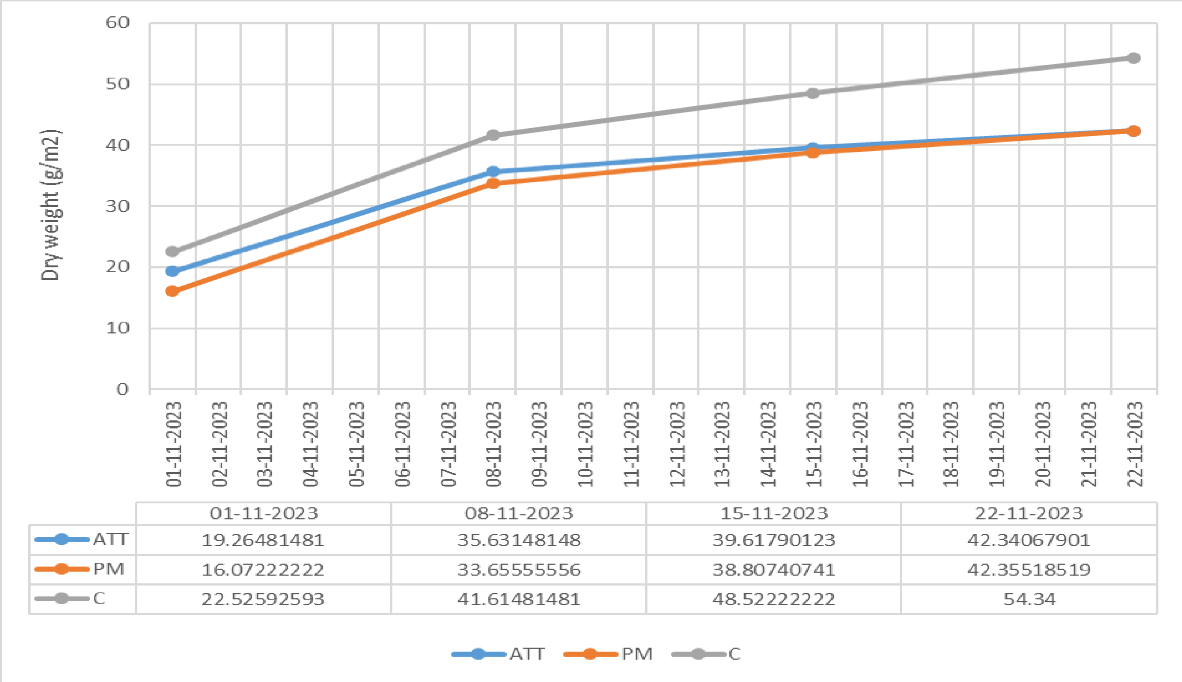


Fig.12. Cumulative clippings dry mass produced by four autumn cuts (ATT = Attraxor, PM = Primo Maxx II, C = Control).

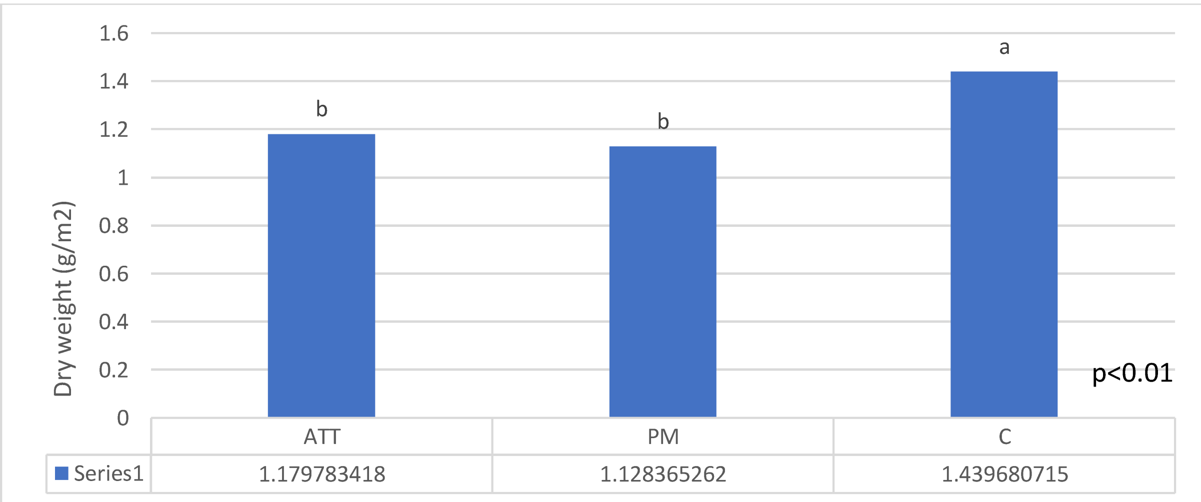


Fig.13. average daily biomass growth of turfgrass subjected to different PGRs (ATT = Attraxor, PM = Primo Maxx II, C = Control).

5.7 Germination

Germination is the process by which a plant grows from a seed into a seedling. Seeds remain dormant until conditions are favourable for germination. All seeds need water, oxygen, and optimal temperature to germinate. We did a germination test where 50 seeds were placed in a Petridis with 4 replications and placed in an incubator for 7 days at 32℃: The results of the germination test on *Poa annua* seeds showed 44 germinations out of 50 getting an 88% germination for the 1st plate, 34 germinations out of 50 getting a 68% germination for the 2nd, 36 germinations out of 50 getting a 72% germination for the 3rd, and finally 40 germinations out of 50 getting an 80% germination for the 4th. With this test, we can now predict an approximate germination on the field. In figure 9, we can now graphically see the difference in the germination percentage and the number of seeds that were germinated.

As observed from figures (figure15, 16, and 17) the germination of *poa annua* is high in the case of ATTRAXOR plots as compared to that of Primo Maxx II and the control. The seed head number does not signify anything but the higher seed head number in ATTRAXOR may be due to it favouring the germination or due to climatic conditions, but it is not clear why this thing is happening. More research is needed so as to provide scientific evidence for the same. The seed head height in figure15 shows that the ATTRAXOR is working well in the spring, but when the temperature starts to rise, the effect starts to decrease, and the seedhead height starts elongating. However, the effect was the opposite in the case of Primo Maxx II. The height of the seedhead decreased in the plot where Primo Maxx II is applied. In the case of control, the height of the seed head remains similar round the season. The germination of *Poa annua* does not affect the experiment as there were so many other external factors that might affected the working of ATTRAXOR on *Poa annua,* which needs time and further exploration so as to get a concrete answer.

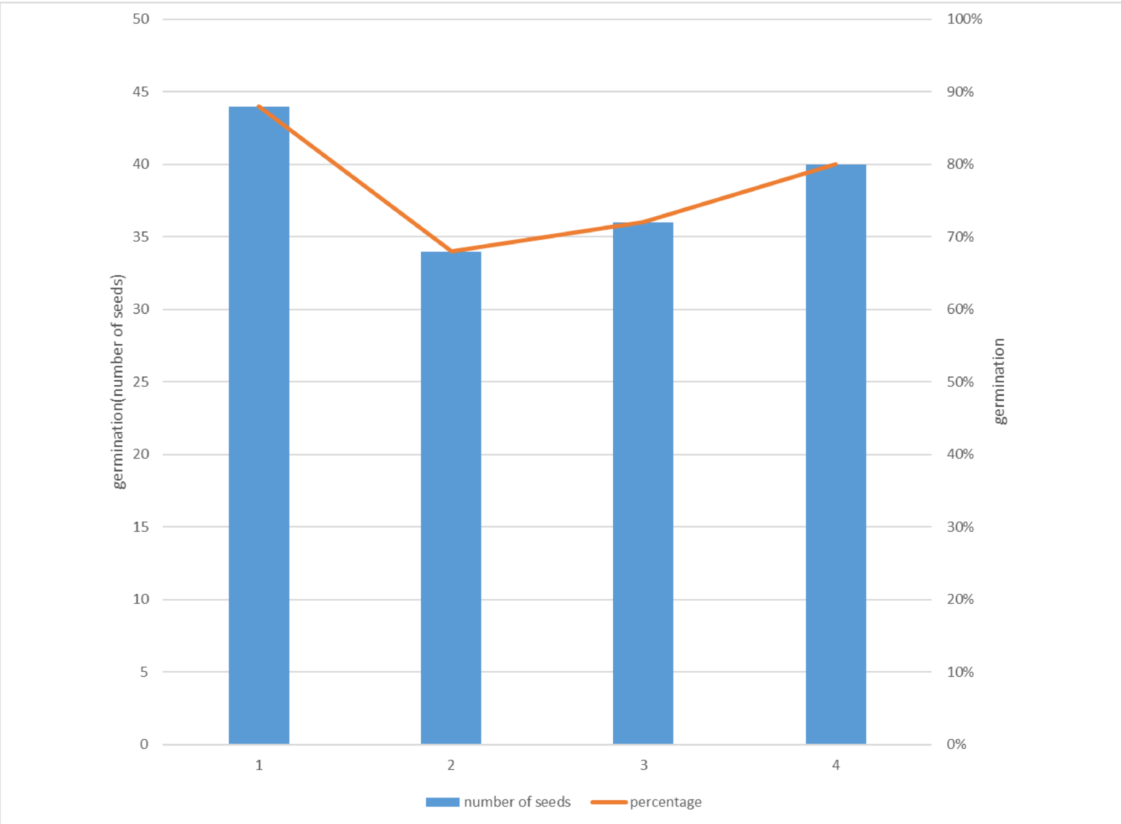


Fig.14. Germination percentage and the number of *Poa annua* seeds germinated out of 50 seeds in growth chamber.

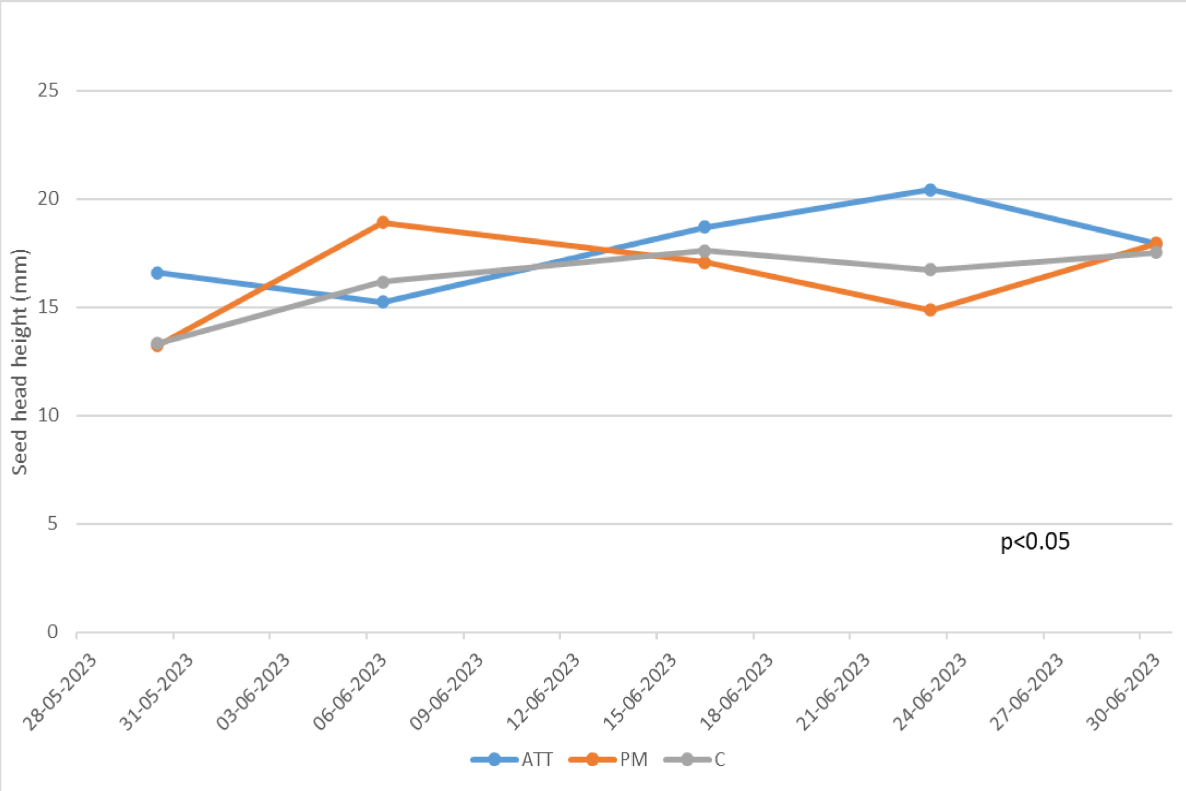


Fig.15. Seedhead height over measurement dates (ATT = Attraxor, PM = Primo Maxx II, C = Control).

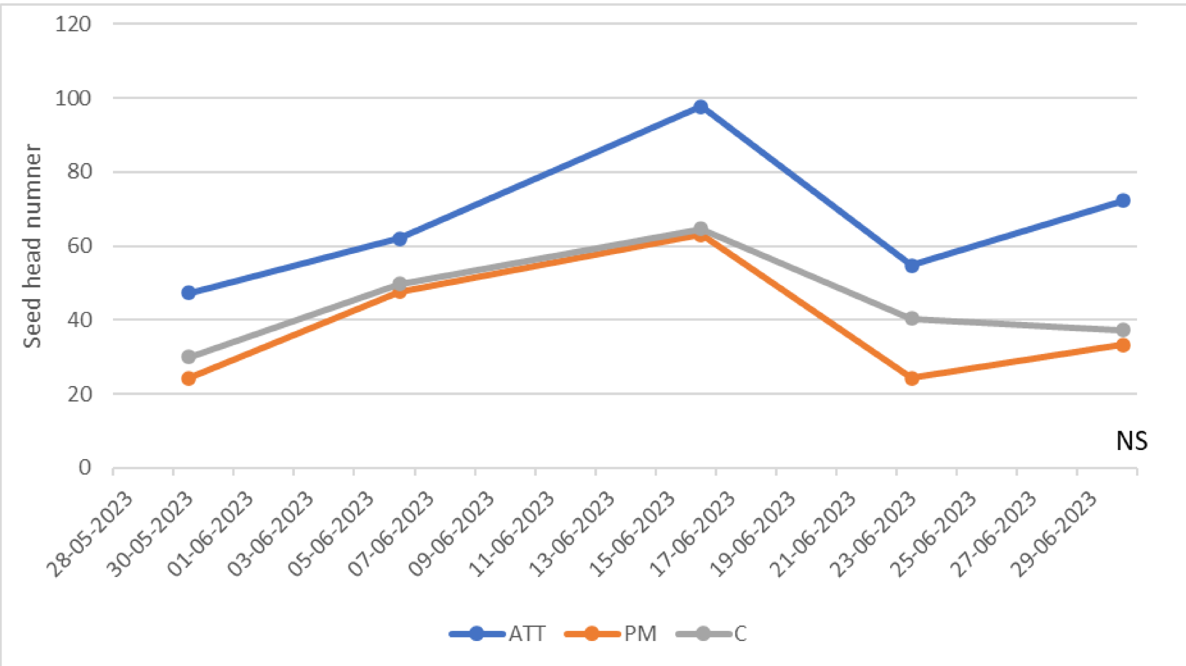


Fig.16. Seedhead number over measurement dates (ATT = Attraxor, PM = Primo Maxx II, C = Control).

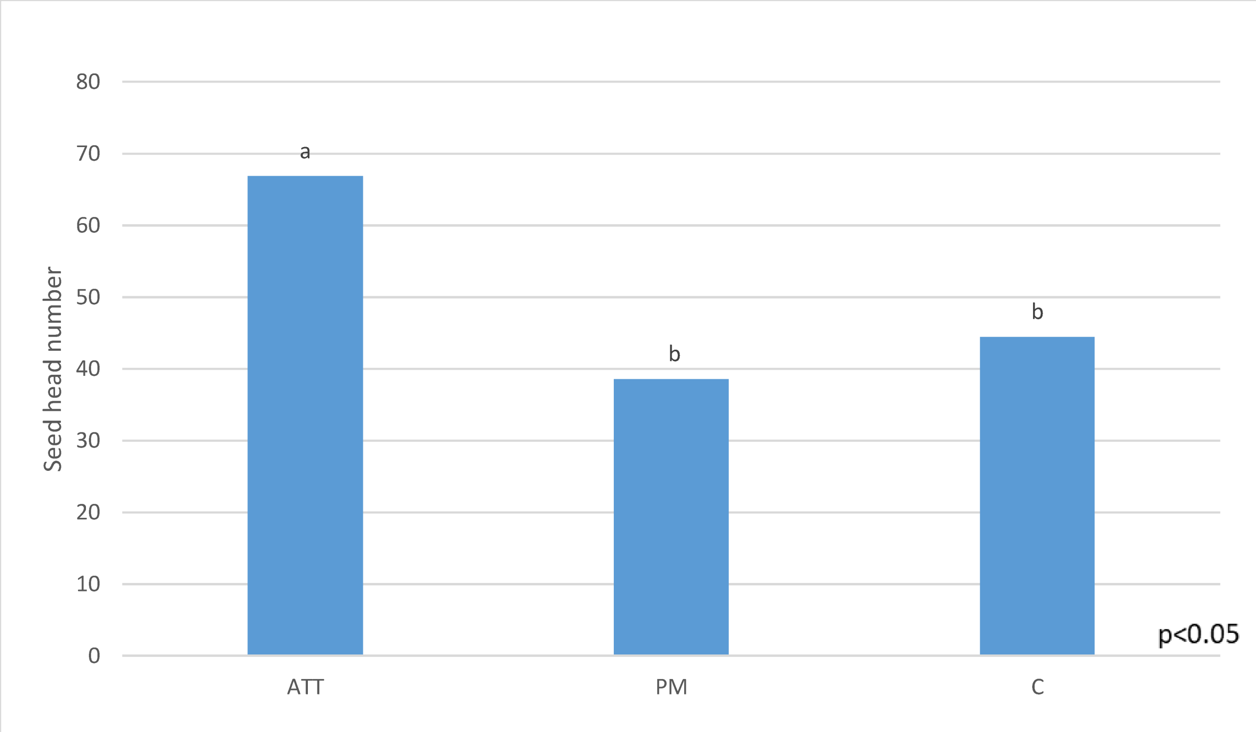


Fig.17. Average seedhead number of the three treatments compared (ATT = Attraxor, PM = Primo Maxx II, C = Control).

6. Conclusions

The findings of this study provide valuable insights into the performance of the plant growth regulators Primo Maxx II and the ATTAXOR during the spring and the fall season. The results demonstrate that the treatments had a significant impact on the *Lolium perenne /poa pratensis* and *poa annua*, as indicated by the statistical analysis. Regarding the color of the bermudagrass, there was no significant difference observed among the three plots with PGRs and the control however, the ATTRAXOR gave a better result in the first few months, but as the winter hits the Primo Maxx II and ATTRAXOR both had similar results with very little to negligible differences. The quality of the turf is dependent on various factors including the temperature, rainfall, solar radiation, weeds, wind, mowing practices and pests and diseases. As observed throughout the year, there were fluctuation in the quality during the summer and then it reached the optimal grade in fall season, as we approached the winter, due to powdery mildew infestation the quality fell substantially, but soon it regained with best management practices. The NDVI (Normalized Difference Vegetation Index) analyzed the effect of cultivar and treatment on the Normalized Difference Vegetation Index (NDVI) of three test blocks. The statistical analysis revealed that three PGR has a significant effect on the NDVI at a significance level of $p < 0.05$. Additionally, the interaction between PGR and treatment showed a significant effect on the NDVI at a higher significance level. The significant effect of cultivar on NDVI suggests that different PGR exhibit variations in their vegetative growth and health. Moving on to the growth parameters we observed that with seasonal variation and precipitation, the growth is also affected. The ATTAXOR plots showed a similar growth pattern as that of the Primo Maxx II and the control in the beginning but gradually started to perform well and started to show retarded growth as compared to Primo Maxx II and the control, with averaging daily growth of 0.17 cm. To conform this we performed the dry mass analysis and got the confirmatory results. In *Poa annua* plots, we found that the ATTRAXOR plots had more germination than the Primo Maxx II and the control. This phenomenon could be due to ATTRAXOR favoring the germination process. In case of *poa annua* we found that there are more seed head formation in

ATTRAXOR plots as compared to that of Primo Maxx II and control. This phenomenon is due to unknown reason, further research is needed to unfold the reason behind higher germination and seed head formation.

In summary, the results of this study suggest to analyze whether the ATTRAXOR can perform well or at par with the already available Plant growth regulator Primo Maxx II; this trial includes parameters like, color, quality, NDVI, germination, daily growth rate, temperature, precipitation and biomass. These findings contribute to the understanding of how the new product ATTRAXOR holds its ground against Primo Maxx II during the spring and fall seasons.

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