HAMK
Häme University of Applied Sciences

The effect of precipitation, temperature, humidity, and length of the day on the growth of forage grass and soil pH on an organic farm in Kanta-Häme (Southern Finland)

Bachelor's thesis

Climate Smart Agriculture

Autumn Semester 2024

Oshani Bamunu Mudiyanselage

HAMK
Häme University
of Applied Sciences

Name of Degree Programme: Climate Smart Agriculture | Abstract
Author: Oshani Bamunu Mudiyanselage | Year: 2024
Subject: The effect of precipitation, temperature, humidity, and length of the day on the growth of forage grass and soil pH on an organic farm in Kanta-Häme (Southern Finland).

Supervisors: Tiiti Kämäri

This study was conducted at a farm in the Kanta-Häme region of Finland, which is associated with HAMK University of Applied Sciences and focuses on producing feed for dairy cows. Due to declining forage grass yields over the last three years, the study aimed to investigate external factors influencing grass growth and soil pH. The research considered weather data such as precipitation, humidity, length of the day, and atmospheric temperature, which were correlated with the height, sample weight, canopy cover, chlorophyll count of grass, and soil pH from six selected forage grass fields.

Field selection was based on the perennial year of growth, comparing 1st-year and 2nd-year grass fields. Data from the selected fields were collected weekly on Mondays before 10:00h to be precise with the timing of data collection. In contrast, weather data were collected daily from May 6th to July 22nd using local weather station data in Jokioinen. The collected weather data was then converted to a weekly basis for analysis and visualization.

The study utilizes Pearson correlation to examine the relationship between weather factors, grass growth, and soil pH. The results indicated that humidity significantly influences forage grass growth and soil pH. Furthermore, the length of the day positively impacts grass growth and soil pH. At the same time, atmospheric temperature significantly affects canopy cover and soil pH, particularly in the Kanta-Häme region of Finland. However, precipitation does not considerably affect either grass growth or soil pH.

Keywords forage grass, precipitation, humidity, atmospheric temperature, day length, soil pH.

Pages 24 pages and appendices 05 page

Content

Figures

Tables

Graphs

Abbreviations

CA	Canopy average
CCA	Chlorophyll count average
DAH	Daily average humidity
DAT	Daily average temperature
DP	Daily precipitation
HA	Height Average
LD	Length of day
pH	Potential of Hydrogen
SOM	Soil organic matter
WAH	Weekly average humidity
WALD	Weekly average length of day
WAT	weekly average temperature
WP	Weekly precipitation

Appendices

Appendix 1. Table for variation of growth factors of grass with weather data taken as average from all grass fields

Appendix 2. Variation of weekly precipitation (WP) with the growth factors of grass data taken as the average of all grass fields**.**

Appendix 3. Variation of weekly average temperature (WAT) with the growth factors of grass data taken as the average of all grass fields**.**

Appendix 4. Variation of weekly average humidity (WAH) with the growth factors of grass data taken as the average of all grass fields**.**

Appendix 5. Variation of the weekly average length of day (WALD) with the growth factors of grass data taken as the average of all grass fields**.**

1 Introduction

Out of the total land on Earth, 40% is covered with grasslands, a primary feed source for livestock farming (Haung et al., 2020). Forage is widely used in livestock due to its high protein content, high digestibility, and palatability, which are significant needs for the health and productivity of ruminants. Feeding forage can fulfil these needs, as it is an effective source of nutrients at a low cost. (Deepika, 2023)Therefore, it is vital to measure the forage yield because this is a guideline for farm management as a risk management procedure. Using the available forage yields produced in a livestock farm, the productivity data can be applied to sell excess forage, purchase supplementary amounts, calculate feeding requirements and proceed with recommendations, plan grazing patterns, and manage the herd count. (Lemus, 2007).

The work is implemented on the Mustiala farm since there was a gradual drop in forage yields when comparing forage yields from 2021-2023 (HAMK University, n.d.). During this work, the growth of grass fields under the first and second perennial years will be evaluated using the height of the canopy, which affects the cut length of the harvest, giving more yield. This shows the vertical growth of the crop. The canopy cover will be analyzed using software called 'Canopeo,' which can be used as a mobile application on the fields during observation. This data will enhance the grass coverage on the fields that demonstrate the horizontal growth of the forage grass via runner stems. The tiller development and height directly affect the amount of light the plants receive. (Macedo et al., 2021).

Weekly analysis weight of a sample would be taken from a definite surface area, which would provide guided data that could be linked with the total yields of the selected fields. Chlorophyll count measurement supports conclusions on the duration of light and the growth of the crop, as it affects the photosynthetic rate. (Haung et al., 2020). pH data collected weekly will provide information on how weather influences the soil pH of the selected grass fields, which will guide future management practices. Weather is an uncontrollable external factor that affects the crop during the growing season, influencing its growth factors. Therefore, rainfall data, duration of light, and humidity will be measured. This work may affect the estimation of the yield of forage grass to promote food security and lead to adaptations for future climatic changes.

2 Background information

The data collection and analysis foundation is based on an organic farm in Mustiala, part of the HAMK University of Applied Sciences. HAMK Mustiala farm is in the Kanta-Häme region (Southern Finland) and serves as a research and educational center. The farm encompasses 185 hectares to produce feed for approximately 75 dairy cows. Both crop production and dairy production at the farm have transitioned to organic methods. Crop production became organic in 2018, followed by dairy production in 2020. This indicates a commitment to sustainable and environmentally friendly farming practices. (HAMK University, n.d.)

The work is related to the forage fields and yields on the farm. Forage grass plays a central role in the feeding system of milking cattle. According to EU regulations, the Finnish government aims to develop production without damaging the environment or the welfare of humans, animals, and plants. (Kuosmanen et al., 2021)Therefore, crop rotation plays a significant role in a farming system, as organic farming restricts chemical fertilizing, growth stimulators, advanced tillage practices, and other chemicals, including pesticides and herbicides. (Mamiev, 2024). The following table gives the recommended crops for crop rotations for cattle farms in Southern Finland based on the soil type.

Table 1 Crop rotation plans for cattle farms in Southern Finland (Rajala, 2006).

Type of soil	1st year	2nd year	3rd year	4th year	5th year	6th year
Clay soil	Oats+ Clover	Forage grass	Forage grass	Forage grass	Winter wheat	Pea/ Oats
Light mineral soil	Oats+ Clover	Forage grass	Forage grass	Forage grass	Rye/Oats	Pea/Oats
Humus rich soil	Barley+ Clover	Forage grass	Forage grass	Forage grass	Oats	Pea+ Clover
Peatland	Barley+ Clover	Forage grass	Forage grass	Forage grass	Oats	Oats

The objectives of including forage grass in crop rotation are to increase soil quality, increase water infiltration rate, reduce diseases to cereal crops, reduce weed density, and maintain high carbon capturing.(Manitoba Forage Council, n.d.)

When observing yield data of forage grass in Mustiala farm in 2021-2023, the yield per hectare dropped in 2022 and 2023 compared to 2021. Even though the field area was increased for growing forage, the farm did not reach the average total yield in 2022 and 2023. The following table shows the data regarding forage grass yields of Mustiala from 2021-2023.

Table 2 Forage grass yield in Mustiala from 2021-2023(HAMK University, n.d.)

Year	2021	2022	2023
Land area	74	67	82
Yield kg/ha	5967	3084	4870
Total yield kg	443945	207121	399340
Total yield t	444	207	399

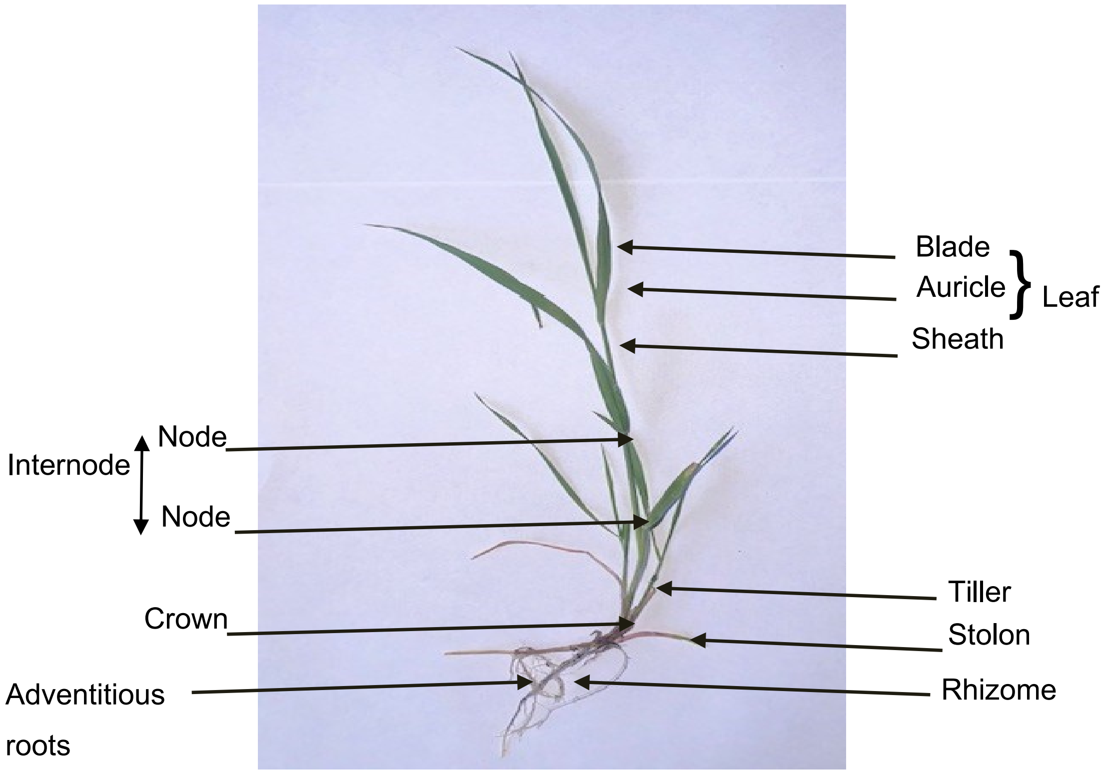
Assuming that forage grass growth and soil pH are affected by external factors like weather data (daily precipitation-DP, daily average temperature-DAT, daily average humidity-DAH, length of the day-LD), relevant data were collected weekly on six selected forage grass fields, where three for each 1st year and 2nd-year grass fields. Data obtained from the grass growth and pH are used to determine the yield of the forage grass every week.

For comparison, the fields are selected based on the year of growth. To increase reliability, the field selection was made randomly after considering the time taken for the data collection; the data must be collected on the same day.

2.1 Structure and morphology of forage grass.

Grass is the fifth most prominent member under the angiosperms or flowering plants and the second largest member in monocotyledonous plants; grass belongs to the Grass family with the scientific name *Poaceae* or *Graminae* (Paleontological Research Institution, 2023). It is grouped further into 650-785 genera, which includes around 10,000 species. Most of the species are C_4 photosynthetic and are also called warm-season grass. The other species is the cool-season grass, the C_3 photosynthetic species. Grass can be annual or perennial, and they are highly capable of adapting to temperature and rainfall changes and grow in most of the regions on Earth, including humid tropics, sub-polar regions, arid areas, and highly elevated areas. (J. et al., 2017).

Fig: 1 Parts of the grass plant



After germination, the water intake for further development is initiated by the roots that appear first, which are called primary roots. (J. et al., 2017). With the fast absorption of water and minerals, the coleoptile is moved upwards. Then, it elongates to the soil surface to form the first leaf. After the development of the first three leaves, the tillering stage is initiated. The seed and the primary roots have disappeared at this stage. At the appearance of the fourth leaf, secondary tillers appear from the primary tiller, which is considered the complete tillering stage. (Peeters & Nilsdotter-Linde, n.d.).

Clover (Trifolium), a legume originating in Europe, is the other main crop found in Mustiala grass fields. It grows low to the ground by spreading from stems/stolons. The leaf has three leaflets, which may have a watermark on top. Leaves and roots grow at nodes of the stem. This species can survive cold weather conditions. The inflorescence has 40-100 florets, and it rises along the stalks of the leaf. Other grass varieties are benefited from this legume since it fixes nitrogen.(St.John & Ogle, 2009)

2.2 Influence of precipitation on the growth of forage grass.

The precipitation rate in the Northern Hemisphere increased in the 20th century. The precipitation pattern directly influences the soil moisture in the temperate zone. Soil moisture is a significant characteristic that affects crops, mainly during summer. Rainfall pattern and grass growth are co-related,(Hurtado-Uria et al., 2013) resulting in low growth during dry seasons due to a lack of crop productivity. Rainfall is a crucial meteorological factor influencing grass growth, especially in temperate zones. Once favorable temperatures are reached, water availability from rainfall initiates and sustains grass growth. Conversely, grass leaves may turn brown during high and unfavorable temperatures due to heat stress and increased transpiration. Rainfall helps the grass recover and thrive again by providing the necessary water. (Hurtado-Uria et al., 2013)

Crops receive water stored in the upper parts of the soil, mainly via precipitation. Tillage is closely related to rainfall, affecting grasses' total production capacity. If the precipitation that is required during the growth period is not received by the grasses, the negative growth pattern of the grass cannot be amended.(Patton et al., 2007). Lack of rainfall in summer is an extreme weather condition that negatively affects grass growth. In addition, the mean daily temperature is closely related to grass productivity, influencing various physiological processes and overall plant health.(Hurtado-Uria et al., 2013).But at the end of the research work, Hurtado-Uria et al., (2013) identified that there is no significant relationship between rainfall and grass growth.

Soil undergoes significant changes in the SOM content and pH changes after rainfall. This change varies between a SOM 1-7% decrease and a pH increase of 0.2-0.4. This affects the growth conditions of the crops. (Patiño-Gutiérrez et al., 2024).

2.3 Soil pH and influence on the growth of forage grass.

The measurement of acidity or alkalinity, i.e., soil’s concentration of H+ ions in an aqueous medium, is called soil pH. This is a factor that influences the presence of available nutrients for crops. Soil pH depends on the fertilizing plan, rainfall pattern, crop rotation, soil type, methods of land use, SOM, and parent rock. pH 7 is the optimum pH range favorable for crops and microbes. The productivity of crops drops if the pH level declines below 5.5. A further drop in pH dissolves toxic elements like Al and Mn, damaging the crops' roots. This controls the absorption of water and minerals into the crop by blocking the osmosis process. (Oshunsanya, 2019)

PH levels can influence soil microbial activities, and high pH conditions can promote microbial processes that enhance the decomposition of soil SOM. This phenomenon is more prominent in soils with high phosphorus (P) levels and significant calcium (Ca) binding capacity. (Deru et al., 2023). For crops, the preferable pH range is from 5.5 to 7.5. Heavy rainfall is a crucial factor for low pH in soil, and the reason is that the pH of rainwater is about 5.7, as it gets combined with atmospheric CO_2 to form carbonic acid. This condition would be further developed via the root respiration process. Continuous nutrient uptake by plants increases H+ ions in soil and causes low cation exchange capacity of the soil. Similarly, soil with high pH has a low infiltration rate and low water retention, which would lead to crops with water-stressed conditions. (Oshunsanya, 2019). Optimum pH conditions affect crop plants directly and indirectly in their growth process, which affects crop yield.

2.4 Role of air temperature on the growth of forage grass.

In temperate zones, grass growth during winter is minimal due to low temperatures, which can be referred to as no growth during this season. As the late summer stages approach, the growth rate of grass also declines. For example, the physiological growth factors of ryegrass (*Lolium perenne L.*), such as photosynthesis rate, respiration, spring growth, heading, and transpiration, are directly influenced by temperature. Perennial ryegrass (*Lolium perenne L.*) requires a period of low temperature, known as vernalization before it can adapt to the summer season. This period helps the grass transition and prepare for the warmer months. Growth of perennial ryegrass is initiated when temperatures rise above 5 degrees Celsius. (Hurtado-Uria et al., 2013).

If water is available, grass begins growing once the surface temperature exceeds 0^0C. However, if the temperature rises above the optimum levels, the leaves turn brown due to increased stress. Higher temperatures increase transpiration rates, causing the grass to lose more water. When rainfall occurs, the grass can revive and thrive again as it receives the necessary water to balance the increased transpiration and meet its physiological needs. (Patton et al., 2007).

Air temperature and soil temperature are directly proportional to grass growth. Temperature plays a crucial role in grass growth throughout all seasons in the temperate zone. Soil temperature, influenced by air temperature, is a positive factor for grass growth. When air temperatures are conducive, they warm the soil, creating an environment that promotes grass growth. Conversely, soil temperatures drop when low air temperatures lead to reduced or no grass growth. Maximum and minimum temperatures significantly influence grass growth and soil temperature, which are crucial for grass development. The interplay between these temperatures determines the overall health and growth rate.(Hurtado-Uria et al., 2013).

2.5 Effect of the day length on the growth of forage grass.

In temperate regions, grass growth is affected by the amount of sunshine the plant receives since it has apparent variations between winter and summer. Grass growth is maximum during late spring and early summer, as it is the period of obtaining optimum radiations from the sun. Solar radiation is a critical factor that influences the growth and development of crops. Photosynthesis is maximized in the presence of sunlight, and chlorophyll in plants is engaged highly in the process of photosynthesis. (Hurtado-Uria et al., 2013). Therefore, the long duration of light increases available carbohydrates for the plant, which supports growth and development (Xu et al., 2024).

Long duration of light increases the canopy average photosynthetic rate of the grass. Water-soluble carbohydrates in leaves are increased when the duration of light is between 14-22 hours, which promotes the tillering of grass. The presence of adequate amounts of light also improves the respiration rate of crops. Extended light durations positively influence the increase of dry mass accumulation, tillering, rhizome development, and the increase of leaf surface area. (Xu et al., 2024).

2.6 Influence of humidity on the growth of grass.

Atmospheric moisture or humidity greatly affects plant growth and development. Humidity plays a significant role in efficiently using available water for crops. Some crops are highly sensitive to humidity levels, and humidity influences all plants' transpiration rates because the atmosphere's humidity regulates stomata. This affects other plant processes, such as water gradient, photosynthesis, nutrient flow, and temperature control. (Tibbitts, 1979). Therefore, humidity is a critical factor in productional crops, affecting the photosynthetic rate and water balance. (Chia & Lim, 2022).

Once the humidity levels are below the optimum level, the stomata's resistance increases, and CO_2 intake is limited. Similarly, once the humidity level exceeds optimum levels, it affects leaf development due to an imbalance in nutrient absorption with reduced transpiration rates. Since humidity and atmospheric temperature are directly proportional, unfavorable humidity levels affect the photosynthetic rates of crop plants and yields. Plants grow faster in highly humid atmospheres compared to plants that grow in low-humid atmospheres. This affects the development of physical factors like the surface area and dry weight of leaves (Chia & Lim, 2022).

Since atmospheric temperature directly affects the processes of crop plants like transpiration, stomatal regulation, water potential, photosynthesis, nutrient flow, plant temperature, and moisture condensation, it plays a significant role in the growth and yield of crop plants (Tibbitts, 1979).

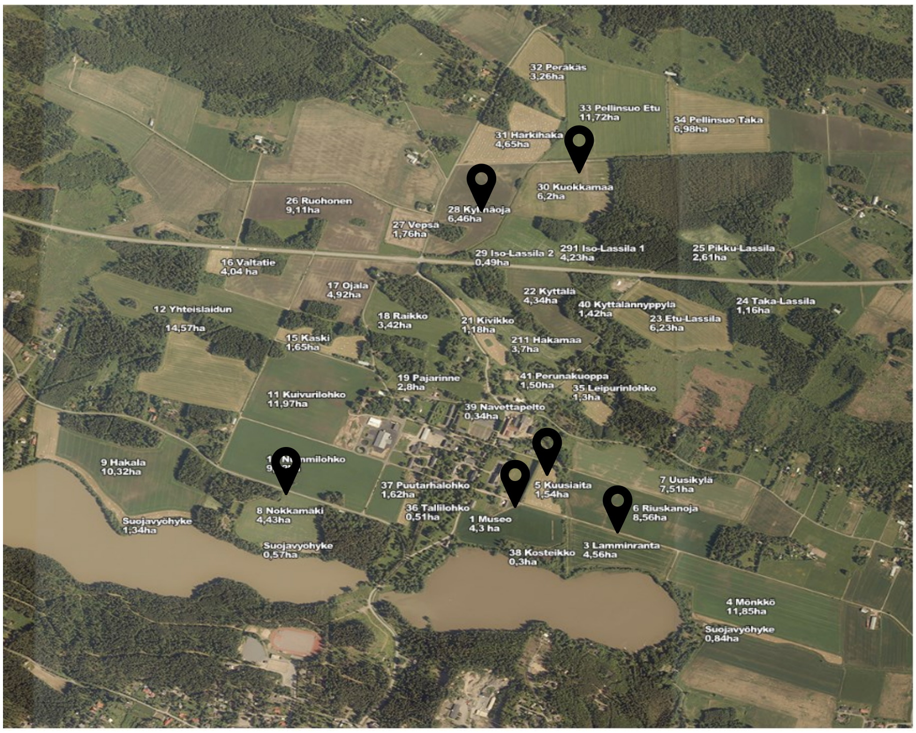
3 Methodology

The data collection assumed that forage grass growth is affected by external factors such as weather. Relevant data were collected weekly on six selected forage grass fields, three for each 1st-year and 2nd-year grass fields. Data was collected randomly from three points of each field, and the points were aligned diagonally from the margin to the center of each field.

Table 3 Selected grass fields based on the perennial year

1st-year grass fields	2nd-year grass fields
01-Museo	05-Kuusiaita
03- Lamminranta	28-Kylmä-oja
08-Nokkamäki	30-Kuokkamaa

Fig: 2 Location of selected fields for the data collection in Mustiala Farm (HAMK University, n.d.)



Data obtained from grass growth are used to determine the yield of the forage grass every week. The following data were collected to assess the growth of the grass fields, and these data were collected in Microsoft Excel to calculate the correlation between factors of grass growth and other external factors.

Canopy height: This was measured using a meter scale from the three points of each field and recorded as a weekly average.

Fig: 3 Obtaining canopy height from grass fields.

Weight of grass samples: A 50x50 cm^2 and 10cm high wooden frame was used to obtain samples from random spots of the grass fields every week. This data was recorded as a factor to determine the weekly weight improvement of the grass.

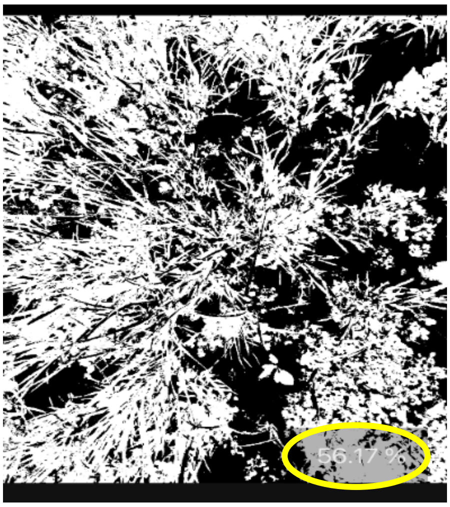
Fig: 4 Cutting grass samples using a 50x50 cm2 frame 10 cm above ground level

Fig: 5 Grass samples stored in a sealed plastic bag until weighed

Canopy coverage: To determine the canopy coverage of the grass fields, an application called ‘Canopeo’ was used. A photograph taken 60-70cm above ground level to cover the field canopy is uploaded to a mobile phone application. This data is collected from three spots on each field and used as an average value weekly to determine the growth of forage grass fields.

Fig: 6 Photographed canopy cover of a grass field.

Fig: 7 Percentage of canopy coverage calculated by the 'Canopeo' application.



Chlorophyll count: The chlorophyll count was determined using the ‘Chlorophyll meter.’ Ten random leaves are selected from each grass field and inserted between the space used to obtain the measurement. Later, the machine provides an average value for the chlorophyll count, which is valuable data in determining the development of grass. The chlorophyll meter measurement is the SPAD- Soil Plant Analysis Development. It is used as an indicator of the leaf chlorophyll/ nitrogen composition. This tool can store the collected data, which can be utilized later. (Tan et al., 2021)

Fig: 8 Chlorophyll meter used to determine the chlorophyll count of the grass fields

Yield data: The yield data from each grass field during the first and second cuts was recorded from the Mustiala farm yield data recording book. Some recordings were inaccurate due to mismanagement when recorded on a farm basis. In such cases, the yield was estimated based on the carriage's capacity and the field's size.

Soil samples were collected from each grass field weekly to obtain data about soil pH. The collected samples were dissolved in water for 20-22h, and the pH values of each solution were obtained using a pH meter.

Fig: 9 Measuring pH of a soil sample from a grass field.

Weather data such as DP, DAT, DAH, and LD were obtained from the closest weather station, Jokioinen weather station, which is 17km away from the Mustiala farm. After converting the data into weekly analysis (Weekly precipitation-WP, Weekly average temperature-WAT, Weekly average humidity-WAH, and Weekly Average Length-WALD), these data were applied to determine the growth of the grass fields and factors that influence the grass growth.

Visualizations and statistical methods are applied to analyse how local weather affects the growth of forage grass and soil pH in selected fields to understand the significance of the selected factors. By evaluating and interpreting the results, summarized findings are provided to gain insights for optimizing grass growth in the region of Southern Finland.

4 Results

4.1 Local weather data

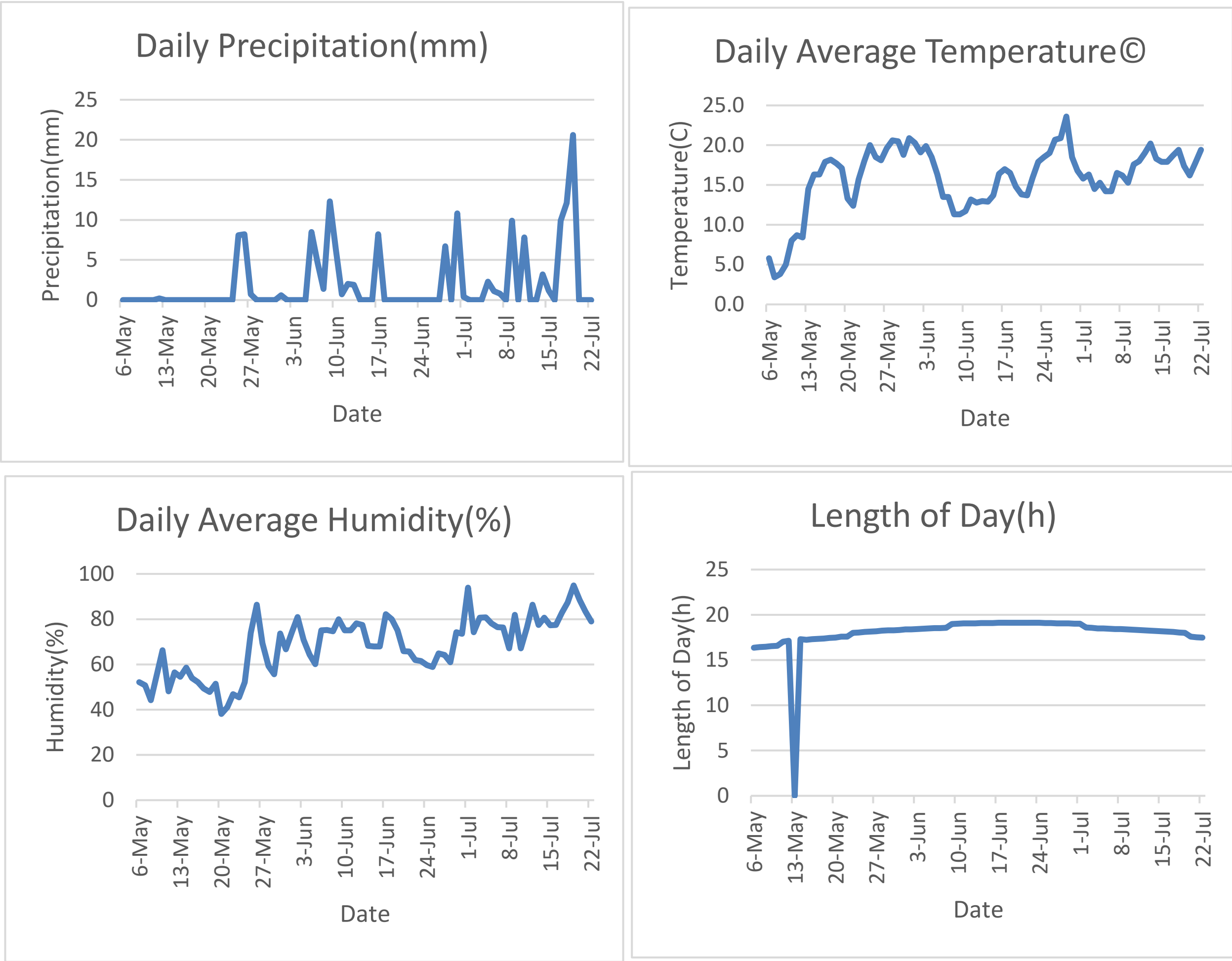
The following table includes the daily weather data from May 6, 2024, to July 22, 2024.

Table 4 Daily weather data obtained from the Jokioinen weather station (Finnish Meterological Institute, n.d.)-2024

Daily weather data	DP	DAT	DAH	LD
Date	**mm**	**^{0}C**	**%**	**h**
6-May	0	5.8	52.1	16.38
7-May	0	3.4	50.8	16.43
8-May	0	3.8	44.2	16.48
9-May	0	5.0	55.5	16.53
10-May	0	8.0	66.3	16.59
11-May	0	8.7	48.1	17.04
12-May	0.2	8.4	56.5	17.14
13-May	0	14.5	54.5	17.14
14-May	0	16.3	58.6	17.29
15-May	0	16.3	54	17.24
16-May	0	17.9	52.2	17.31
17-May	0	18.2	49.3	17.34
18-May	0	17.7	47.8	17.38
19-May	0	17.1	51.5	17.43
20-May	0	13.3	38.1	17.48
21-May	0	12.4	41.1	17.57
22-May	0	15.7	46.8	17.58
23-May	0	18.0	45.5	18.01
24-May	0	20.0	52.2	18.05
25-May	8.1	18.5	73.9	18.11
26-May	8.2	18.1	86.4	18.14
27-May	0.7	19.6	69.3	18.18
28-May	0	20.6	59.3	18.26
29-May	0	20.5	55.6	18.28
30-May	0	18.8	73.7	18.29
31-May	0	20.9	66.7	18.33
1-Jun	0.6	20.3	74.2	18.4
2-Jun	0	19.1	80.9	18.4
3-Jun	0	19.9	70.8	18.43
4-Jun	0	18.5	64.3	18.46
5-Jun	0	16.3	60.1	18.51
6-Jun	8.5	13.5	75	18.52
7-Jun	4.7	13.5	75.2	18.54
8-Jun	1.4	11.3	74.7	18.56
9-Jun	12.3	11.3	79.9	19.00

10-Jun	6.3	11.7	75	19.02
11-Jun	0.7	13.2	75	19.04
12-Jun	2	12.8	78.1	19.06
13-Jun	1.9	13	77.4	19.07
14-Jun	0	12.9	68.2	19.08
15-Jun	0	13.7	68	19.09
16-Jun	0	16.4	67.9	19.10
17-Jun	8.2	17.0	82.2	19.11
18-Jun	0	16.5	79.9	19.11
19-Jun	0	14.8	75	19.12
20-Jun	0	13.8	65.8	19.12
21-Jun	0	13.7	65.7	19.12
22-Jun	0	15.9	61.9	19.12
23-Jun	0	17.9	61.5	19.11
24-Jun	0	18.5	59.7	19.11
25-Jun	0	19.0	58.8	19.09
26-Jun	0	20.7	64.8	19.08
27-Jun	0	20.9	64.2	19.07
28-Jun	6.7	23.6	60.9	19.06
29-Jun	0	18.5	74.2	19.04
30-Jun	10.8	16.8	73.5	19.03
1-Jul	0.4	15.8	93.9	19.01
2-Jul	0	16.3	74.2	18.59
3-Jul	0	14.5	80.7	18.55
4-Jul	0	15.3	80.8	18.51
5-Jul	2.3	14.2	78.1	18.48
6-Jul	1.1	14.2	76.4	18.46
7-Jul	0.8	16.5	76.3	18.44
8-Jul	0	16.2	67.1	18.43
9-Jul	9.9	15.3	81.9	18.39
10-Jul	0	17.6	67.1	18.36
11-Jul	7.8	18	76.2	18.33
12-Jul	0	19	86.4	18.29
13-Jul	0	20.2	77.5	18.26
14-Jul	3.2	18.3	80.7	18.22
15-Jul	1.2	17.9	77.3	18.18
16-Jul	0	17.9	77.4	18.14
17-Jul	9.9	18.7	82.9	18.1
18-Jul	12.1	19.4	87.3	18.05
19-Jul	20.6	17.4	94.9	18.01
20-Jul	0	16.2	88.5	17.57
21-Jul	0	17.8	83.4	17.52
22-Jul	0	19.4	79	17.49

Graph 1 Variation of daily weather data (Finnish Meterological Institute, n.d.)- 2024

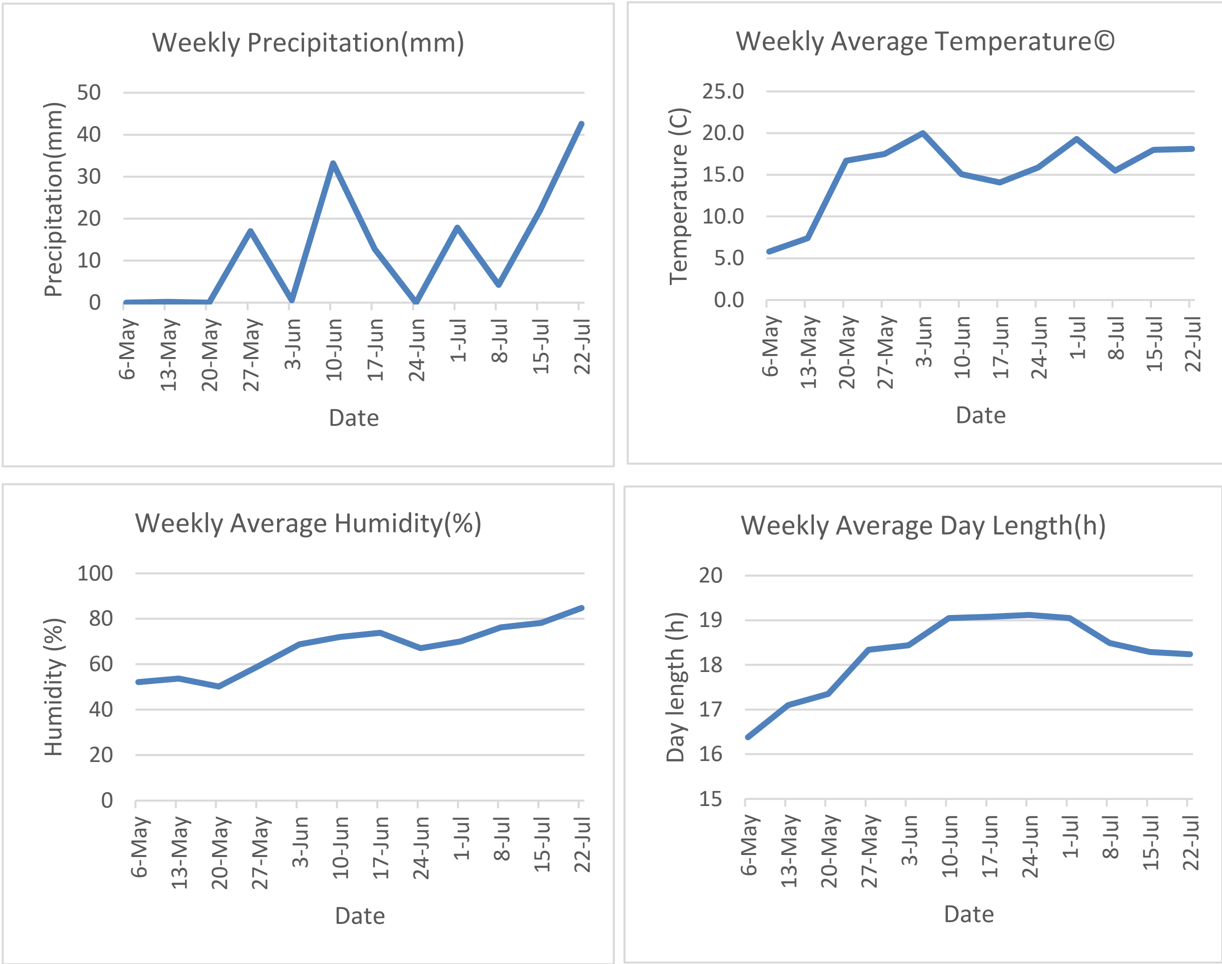


Since this weather data needs to be applied to the grass growth data of the selected fields, these were converted into a weekly version parallel with the days of data from grass fields.

Table 5 Weekly weather data

Date	WP	WAT	WAH	WALD
	mm	**°C**	**%**	**h**
6-May	0	5.8	52.1	16.38
13-May	0.2	7.4	53.7	17.1
20-May	0	16.7	50.21	17.35
27-May	17	17.5	59.31	18.34
3-Jun	0.6	20	68.74	18.44
10-Jun	33.2	15.1	72.03	19.05
17-Jun	12.8	14.1	73.83	19.08
24-Jun	0	15.9	67.07	19.12
1-Jul	17.9	19.3	70.04	19.05
8-Jul	4.2	15.5	76.23	18.49
15-Jul	22.1	18	78.16	18.29
22-Jul	42.6	18.1	84.77	18.24

Graph 2 Variation of weekly weather data obtained from Jokioinen weather station- 2024



4.2 Grass growth data

Grass growth data was recorded weekly from the 6th of May 2024 until the 15th of July 2024. Height(cm), Chlorophyll count, weight of 50*50 cm^2 frame sample-W, and Canopy cover percentage from three random spots from each first-year and second-year grass fields were measured and converted to height average-HA, Chlorophyll count average-CCA, canopy cover average-CA for analysis and to obtain a relationship with weather data.

Table 6 Grass growth data of first-year grass fields in 2024

	Museo					Lämminranta					Nokkamäki				
Date	pH	HA (cm)	CA (%)	W(g)	CCA	pH	HA (cm)	CA (%)	W(g)	CCA	pH	HA (cm)	CA (%)	W(g)	CCA
6-May	0	11	22.12	0	25.5	0	8.67	14.1	0	27.3	0	11.67	28.99	0	26.6
13-May	0	14.33	42.46	3.5	34.1	0	12	26.69	0.65	34.7	0	13.67	55.1	3.08	56.1
20-May	7.1	21.33	62.15	37.5	28.8	7.1	19.33	45.41	5.77	27.1	6.94	24.33	73.57	39.32	34.7
27-May	7.04	27	79.65	75.35	37.8	7.21	22.33	66.15	12.12	24.2	6.74	36.67	82.82	68.26	34.8
3-Jun	7.35	41	76.88	79.38	34.8	7.06	39	65.72	27.88	29.7	7.39	51	82.38	77.41	41.6
10-Jun															
17-Jun	7.41	27.83	51.22	56.47	31.4	7.53	12.56	65.69	7.05	26.8	7.5	15	84.03	14.87	31.6
24-Jun	7.54	31.67	54.69	60.78	31.2	7.71	15.33	67.27	9.66	29	7.73	20.22	84.77	18.72	30.1
1-Jul	7.44	37	73.79	65.08	42	7.33	21.67	68.85	12.33	34.5	7.51	32.5	85.04	53.15	30.5
8-Jul	7.31	57	77.95	88.2	42.5	7.2	23	69.39	14.24	36	7.62	59.5	91.75	98.89	36.21
15-Jul	7.69	60.15	79.43	94.18	40.87	7.68	28.72	79.77	36.48	42.6	7.9	68.76	95.78	150.45	38.9

Table 7 Grass growth data of second-year grass fields in 2024

	Kuusiaita					Kylmä´-oja					Kuokkama				
Date	pH	HA(cm)	CA(%)	W(g)	CCA	pH	HA(cm)	CA(%)	W(g)	CCA	pH	HA(cm)	CA(%)	W(g)	CCA
6-May	0	11.67	10.41	0	20.3	0	11.3	14.74	0	18.4	0	11	14.23	0	35.5
13-May	0	16.67	32.78	3.16	34.1	0	11.5	36.78	1.96	33.4	0	15.67	37.29	5.59	37.7
20-May	7.23	27.67	45.74	18.96	24.9	6.58	15.33	43.06	2.08	26.3	7.32	22.33	49.69	15.76	41.3
27-May	6.08	36.76	64.29	32.77	35.4	6.53	20.33	51.14	17.09	34.2	7.14	30.67	60.42	29.4	39.4
3-Jun	7.01	45	65.67	50.21	35	7.26	32.65	68.86	31.94	36.5	7.26	43	73.86	76.88	38.9
10-Jun															
17-Jun	7.12	32.87	50.68	12.7	36.6	7.24	21.55	43.7	10.02	35.97	7.78	28.95	75.05	29.34	41.91
24-Jun	7.3	38.67	53.57	19.7	36.2	7.15	24	46.53	12.77	37.6	8.13	33.16	77.62	38.81	44.6
1-Jul	7.23	41.2	70.21	25.84	39.2	7.23	25.67	53.64	24.42	45.3	7.58	36.6	76.83	61.17	34.2
8-Jul	7.09	45.3	74.76	42.42	39.4	7.36	32.67	63.88	67.27	44.28	7.6	45.72	80.53	78.26	41.2
15-Jul	7.87	45.25	73.15	57.3	26.1	7.35	38.2	67.54	86.93	42.1	7.63	51.83	83.9	83.94	45.3

Graphical representation of variation of grass growth data and weather data are represented in Appendix 1-6. These graphs would be helpful to receive a summary of the above tabulated data.

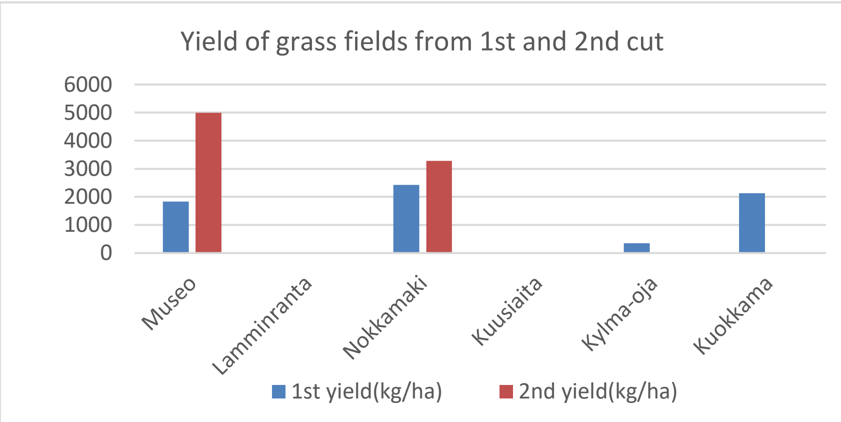
4.3 Yield data

Table 8 Yield data from the first and second cuts of grass in 2024

Field	1st yield(kg/ha)	2nd yield(kg/ha)
Museo	1829	4990
Lamminranta		
Nokkamäki	2430	3285
Kuusiaita		
Kylmä-oja	353	
Kuokkamaa	2135	

Some grass fields were not harvested due to the lack of growth and overgrowth of weeds; therefore, the results were not applicable in comparison.

Graph 3 Yield comparison from 1st and 2nd cut of grass fields in 2024



5 Data analysis

The results were analyzed using Pearson correlations between weather data for each grass field to identify the factors affecting the growth of forage grass.

Table 9 Pearson correlation between weather data and growth data of first-year grass fields in 2024

Weather factor	Museo					Lamminranta					Nokkamäki				
	H	CA	W	CCA	pH	H	CA	W	CCA	pH	H	CA	W	CCA	pH
WP	0.47	0.53	0.56	0.63	0.45	0.24	0.61	0.49	0.34	0.46	0.43	0.53	0.56	0.14	0.44
WAH	0.87	0.58	0.81	0.67	0.65	0.46	0.83	0.68	0.54	0.64	0.66	0.77	0.64	0.4	0.68
WALD	0.53	0.62	0.76	0.53	0.83	0.36	0.89	0.42	0.1	0.83	0.33	0.85	0.32	0.23	0.84
WAT	0.66	0.9	0.86	0.56	0.93	0.78	0.88	0.69	0.12	0.92	0.63	0.86	0.64	0.7	0.92

Table 10 Pearson correlation between weather data and growth data of second-year grass fields in 2024

Weather factor	Kuusiaita					Kylmä-oja					Kuokkamaa				
	H	CA	W	CCA	pH	H	CA	W	CCA	pH	H	CA	W	CCA	pH
WP	0.47	0.57	0.44	0.17	0.43	0.46	0.41	0.5	0.53	0.44	0.5	0.49	0.42	0.1	0.43
WAH	0.82	0.76	0.68	0.52	0.66	0.88	0.73	0.77	0.83	0.68	0.87	0.87	0.85	0.43	0.64
WALD	0.82	0.78	0.47	0.77	0.8	0.63	0.66	0.34	0.8	0.84	0.69	0.91	0.48	0.37	0.84
WAT	0.9	0.88	0.78	0.42	0.92	0.72	0.84	0.46	0.64	0.92	0.79	0.82	0.74	0.31	0.91

5.1 Pearson correlation between weather data and grass height data.

Table 11 Pearson correlation between the height of grass and weather data in 2024

Weather factor	Pearson correlation with H of grass					
	Museo	Lamminranta	Nokkamäki	Kuusiaita	Kylmä-oja	Kuokkamaa
WP	0.47	0.24	0.43	0.47	0.46	0.5
WAH	0.87	0.46	0.66	0.82	0.88	0.87
WALD	0.53	0.36	0.33	0.82	0.63	0.69
WAT	0.66	0.78	0.63	0.9	0.72	0.79

According to the table, there is a strong positive correlation between the height of all the second-year grass fields and one first-year grass field (Museo) and humidity in the area. Also, the WAT positively affects the height of all the grass fields. WALD shows a slight influence on the height of grass in its second year of growth. However, the rest of the weather data does not show any correlation for the height development of grass.

5.2 Pearson correlation between weather data and grass canopy cover data.

Table 12 Pearson correlation between the canopy cover of grass and weather data in 2024

Weather factor	Pearson correlation with CA cover of grass					
	Museo	Lamminranta	Nokkamäki	Kuusiaita	Kylmä-oja	Kuokkamaa
WP	0.53	0.61	0.53	0.57	0.41	0.49
WAH	0.58	0.83	0.77	0.76	0.73	0.87
WALD	0.62	0.89	0.85	0.78	0.66	0.91
WAT	0.9	0.88	0.86	0.88	0.84	0.82

All weather factors, such as humidity, length of day, and temperature, positively influence the canopy coverage of grass fields. However, based on the Pearson correlation data, there is no interference between the precipitation rate and the canopy coverage of grass.

5.3 Pearson correlation between weather data and sample weight of grass data.

Table 13 Pearson correlation between the sample weight and weather data in 2024

Weather factor	Pearson correlation with W of grass					
	Museo	Lamminranta	Nokkamäki	Kuusiaita	Kylmä-oja	Kuokkamaa
WP	0.56	0.49	0.56	0.44	0.5	0.42
WAH	0.81	0.68	0.64	0.68	0.77	0.85
WALD	0.76	0.42	0.32	0.47	0.34	0.48
WAT	0.86	0.69	0.64	0.78	0.46	0.74

Based on the Pearson correlation data, grass weight depends on humidity and slightly on the area's temperature. There is no clear pattern between the effect of precipitation and day length on grass weight.

5.4 Pearson correlation between weather data and Chlorophyll count average of grass data.

Table 14 Pearson correlation between the chlorophyll count average and weather data in 2024

Weather factor	Pearson correlation with CCA of grass					
	Museo	Lamminranta	Nokkamäki	Kuusiaita	Kylmä-oja	Kuokkamaa
WP	0.63	0.34	0.14	0.17	0.53	0.1
WAH	0.67	0.54	0.4	0.52	0.83	0.43
WALD	0.53	0.1	0.23	0.77	0.8	0.37
WAT	0.56	0.12	0.7	0.42	0.64	0.31

There is no significant relationship between the chlorophyll count and the weather data in the area. A few exceptions exist in the second-year grass fields, like Kuusiaita and Kylmä-oja, depending on day length and humidity. However, these relationships are insignificant and cannot be used to reach conclusions.

5.5 Pearson correlation between weather data and soil pH of grass fields data.

Table 15 Pearson correlation between the soil pH of fields and weather data in 2024

Weather factor	Pearson correlation with soil pH of soil					
	Museo	Lamminranta	Nokkamäki	Kuusiaita	Kylmä-oja	Kuokkamaa
WP	0.45	0.46	0.44	0.43	0.44	0.43
WAH	0.65	0.64	0.68	0.66	0.68	0.64
WALD	0.83	0.83	0.84	0.8	0.84	0.84
WAT	0.93	0.92	0.92	0.92	0.92	0.91

There is a clear positive relationship between temperature and the length of the day with the pH variation in all the grass fields, and the Pearson correlation value is similar in all the grass fields when compared. The humidity affects the soil pH slightly, and the correlation value is closely related in all the grass fields.

6 Conclusion.

According to the data and its analysis, humidity significantly shows a correlation to the height of grass fields under second-year growth. Canopy cover and weight are correlated regardless of their year of growth. Also, humidity slightly correlates with soil pH irrespective of their year of growth. However, humidity does not significantly correlate with the chlorophyll counts of forage grass. Atmospheric temperature significantly correlates to soil pH and canopy cover, moderately on grass height, and slightly on the weight of forage grass. The length of the day significantly correlates with canopy cover and soil pH and slightly on second-year grass height, but it shows no consistent pattern in its effect on weight or chlorophyll count. As concluded in Hurtado-Uria et al.,(2013) Precipitation does not influence height, weight, chlorophyll count, or soil pH, even though rainfall is expected to impact grass growth positively.

Therefore, humidity is a significant weather component correlating the growth of forage grass and soil pH. Additionally, the length of the day positively correlates with grass growth and soil pH. Atmospheric temperature correlation is significant on the canopy cover and soil pH, especially in the Kanta-Häme region of Finland. According to the collected data, precipitation does not considerably correlate with grass growth or soil pH in the Kanta-Häme region of Finland.

Table 16 Summary of conclusion

Weather factor	Grass field factor				
	Height of grass	**Canopy cover**	**Weight**	**Chlorophyll count**	**Soil pH**
Precipitation	No	No	No	Unclear	No
Humidity	Highly on second-year grass fields	Significant	Significant	Unclear	Slightly
Length of day	Slightly on second-year grass fields	Significant	No	Unclear	Significant
Temperature	Moderately	Significant	Slightly	Unclear	Significant

7 Discussion.

Only sample weight was used during the study to determine the weather factors affecting grass growth. Yield data were not utilized in the conclusions due to missing records from the farm, which impacts the reliability of the data. Linking the yield data from each harvest in future studies would provide more comprehensive results and better achieve the objectives of this research. By integrating this data, researchers can gain deeper insights into the relationship between weather factors and grass growth, identify patterns, and make more accurate predictions. This approach would also help address the limitations caused by missing yield records, thereby enhancing the overall reliability and validity of the study's findings.

This study can be improved by combining fertilization data and field preparation methodologies in future research, as these influence the growth of forage grass and soil pH. Furthermore, data collection should also encompass crop rotation patterns, given their impact on soil conditions and crop growth. Additional weather data like light intensity can be applied in future studies. Data collection can be categorized based on C-3 or C-4 grass types, and it can be further developed by focusing on different species used in the fields. The findings from this study and data from future research can be utilized to develop farm management practices that address the emerging challenges in livestock farming.

References

Chia, S. Y., & Lim, M. W. (2022). A critical review on the influence of humidity for plant growth forecasting. *IOP Conference Series: Materials Science and Engineering*, *1257*(1), 012001. https://doi.org/10.1088/1757-899X/1257/1/012001

Deepika, M. (2023, March 31). *Forage crops and importance in agriculture*. BigHaat. https://kisanvedika.bighaat.com/crop/forage-crops-and-its-importance-in-agriculture/

Deru, J. G. C., Hoekstra, N., Van Agtmaal, M., Bloem, J., De Goede, R., Brussaard, L., & Van Eekeren, N. (2023). Effects of Ca:Mg ratio and pH on soil chemical, physical and microbiological properties and grass N yield in drained peat soil. *New Zealand Journal of Agricultural Research*, *66*(1), 61–82. https://doi.org/10.1080/00288233.2021.1990087

HAMK University. (n.d.). *Welcome to Mustiala campus*. https://mustialanluomutila.fi/en/welcome/

Haung, X., Zhao, G., Zorn, C., Tao, F., Ni, S., Zhang, W., Tu, T., & Höglind, M. (2020). *Grass modelling in data-limited areas by incorporating MODIS data products*. https://www.sciencedirect.com/science/article/abs/pii/S0378429021001969?via%3Dihub

Hurtado-Uria, C., Hennessy, D., Shalloo, L., O'Connor, D., & Delaby, L. (2013). Relationships between meteorological data and grass growth over time in the south of Ireland. *Irish Geography*, *46*(3), 175–201. https://doi.org/10.1080/00750778.2013.865364

J., K., Moore, & Nelson, J. (2017). Structure and Morphology of Grasses. *C. J.*, *1*.

Kuosmanen, N., Yli-Heikkilä, M., Väre, M., & Kuosmanen, T. (2021). Productive performance of organic crop farms in Finland 2010–2017. *Organic Agriculture*, *11*(3), 379–392. https://doi.org/10.1007/s13165-020-00343-x

Lemus, R. (2007, August). *Forage*. https://extension.msstate.edu/sites/default/files/newsletter/forage-news/2007/8.pdf

Macedo, V., Cunha, A., Ebson, C., Domingues, F., Da Silva, W., Lara, M., & Rego, A. (2021). *Canopy structural variations affect the relationship between height and light interception in Guinea Grass*. https://www.sciencedirect.com/science/article/abs/pii/S0378429021001957?via%3Dihub

Mamiev, D. (2024). Agrophysical properties of the soil depending on the crops of the grassland crop rotation. *E3S Web of Conferences*, *480*, 03029. https://doi.org/10.1051/e3sconf/202448003029

Manitoba Forage Council. (n.d.). *Agriculture The Benefits of Including Forages in Your Crop Rotation*. https://www.gov.mb.ca/agriculture/crops/crop-management/forages/print,benefits-of-including-forages-in-your-crop-rotation.html#:~:text=The%20use%20of%20forages%20in,problem%20of%20herbicide%2Dresistant%20weeds.

Oshunsanya, S. (Ed.). (2019). *Soil pH for Nutrient Availability and Crop Performance*. IntechOpen. https://doi.org/10.5772/68057

Paleontological Research Institution. (2023, November 1). *Diversity and classification of grass*. Grasses - Earth@Home: Evolution (earthathome.org)

Patiño-Gutiérrez, S. E., Domínguez-Rivera, I. C., Daza-Torrez, M. C., Ochoa-Tocachi, B. F., & Oviedo-Ocaña, E. R. (2024). Effects of rainfall seasonality and land use change on soil hydrophysical properties of high-Andean dry páramo grasslands. *CATENA*, *238*, 107866. https://doi.org/10.1016/j.catena.2024.107866

Patton, B. D., Dong, X., Nyren, P. E., & Nyren, A. (2007). Effects of Grazing Intensity, Precipitation, and Temperature on Forage Production. *Rangeland Ecology & Management*, *60*(6), 656–665. https://doi.org/10.2111/07-008R2.1

Peeters, A., & Nilsdotter-Linde, N. (n.d.). *Grassland production*.

Rajala, jukka. (2006). *Luonnonmukainen maatalous*. Luonnonmukainen maatalous | HAMK University of Applied Sciences | HAMK Finna

St.John, L., & Ogle, D. (2009). *Plant Guide- White Clover*. Unites States Department Of Agriculture. https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_trre3.pdf

Tan, L., Zhou, L., Zhao, N., He, Y., & Qiu, Z. (2021). Development of a low-cost portable device for pixel-wise leaf SPAD estimation and blade-level SPAD distribution visualization using color sensing. *Computers and Electronics in Agriculture*, *190*, 106487. https://doi.org/10.1016/j.compag.2021.106487

Tibbitts, T. W. (1979). Humidity and Plants. *BioScience*, *29*(6), 358–363. https://doi.org/10.2307/1307692

Xu, Q., Huang, B., & Wang, Z. (2024). *Effects of Extended Daylength on Shoot Growth and Carbohydrate Metabolism for Creeping Bentgrass Exposed to Heat Stress*.

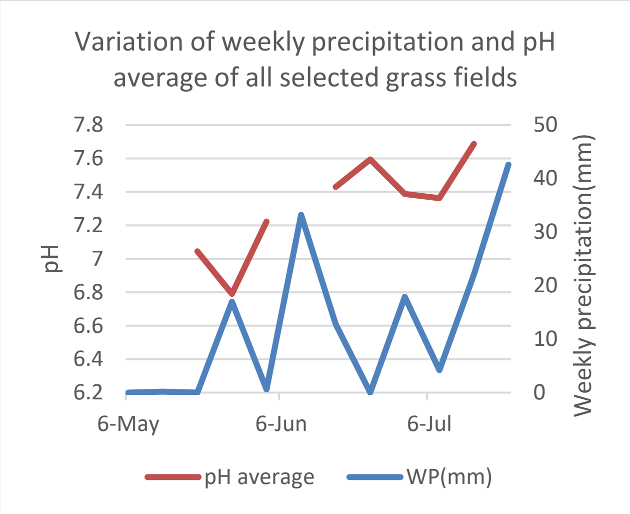
Appendix 1. Table for variation of growth factors of grass with weather data taken as average from all grass fields

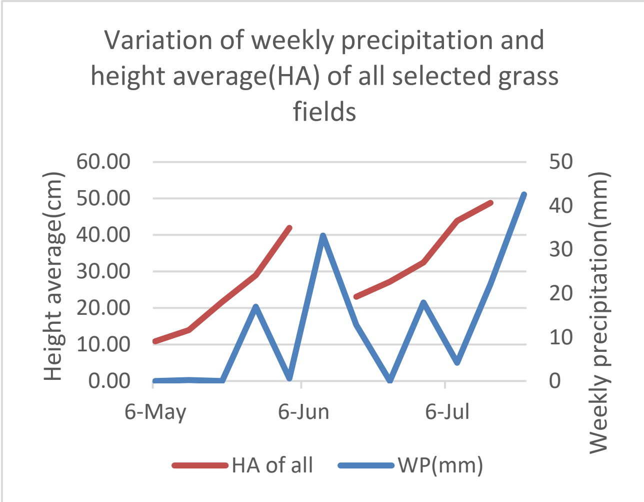
Table 17 Variation of growth factors of grass with weather taken as average from all grass fields 2024

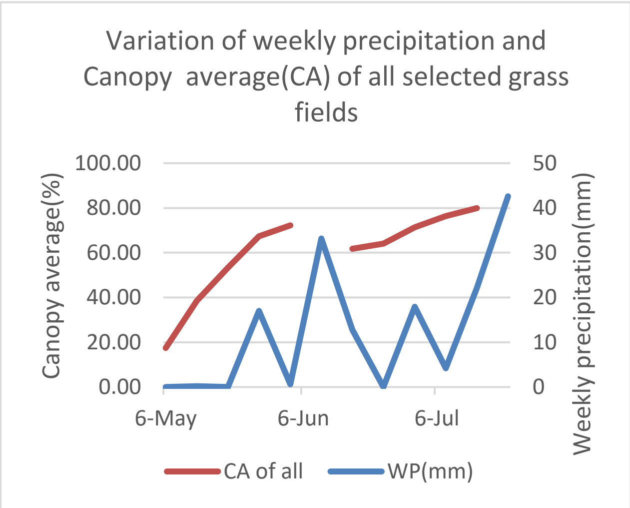
Daily Weather data					Average of all grass field data				
Date	WP(mm)	WAT©	WAH(%)	WADL(h)	pH	HA(cm)	CA (%)	W (g)	CAA
6-May	0	5.8	52.1	16.38		10.89	17.43	0.00	25.60
13-May	0.2	7.4	53.7	17.1		13.97	38.52	2.99	38.35
20-May	0	16.7	50.21	17.35	7.05	21.72	53.27	19.90	30.52
27-May	17	17.5	59.31	18.34	6.79	28.96	67.41	39.17	34.30
3-Jun	0.6	20	68.74	18.44	7.22	41.94	72.23	57.28	36.08
10-Jun	33.2	15.1	72.03	19.05					
17-Jun	12.8	14.1	73.83	19.08	7.43	23.13	61.73	21.74	34.05
24-Jun	0	15.9	67.07	19.12	7.59	27.18	64.08	26.74	34.78
1-Jul	17.9	19.3	70.04	19.05	7.39	32.44	71.39	40.33	37.62
8-Jul	4.2	15.5	76.23	18.49	7.36	43.87	76.38	64.88	39.93
15-Jul	22.1	18	78.16	18.29	7.69	48.82	79.93	84.88	39.31
22-Jul	42.6	18.1	84.77	18.24					

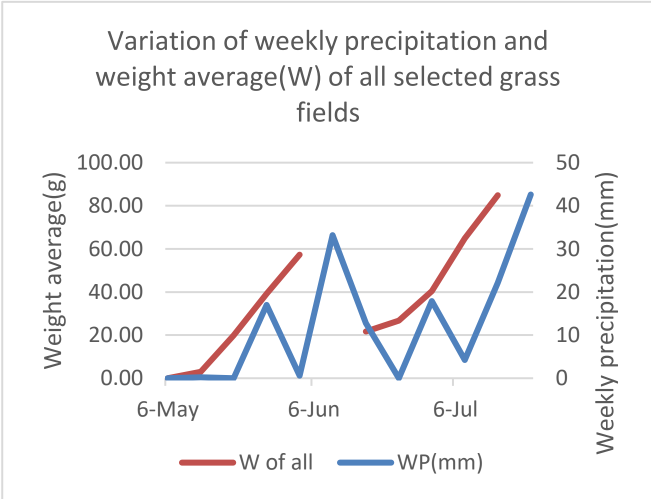
Appendix 2. Variation of weekly precipitation (WP) with the growth factors of grass data taken as the average of all grass fields

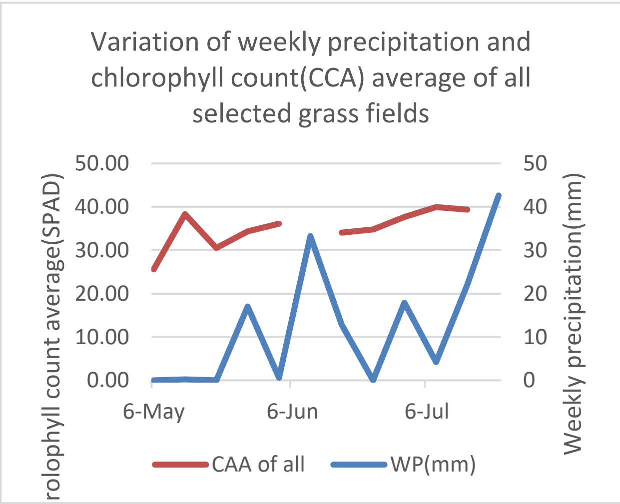
Graph 4 Variation of weekly precipitation (WP) with the growth factors of grass data taken as the average of all grass fields in 2024





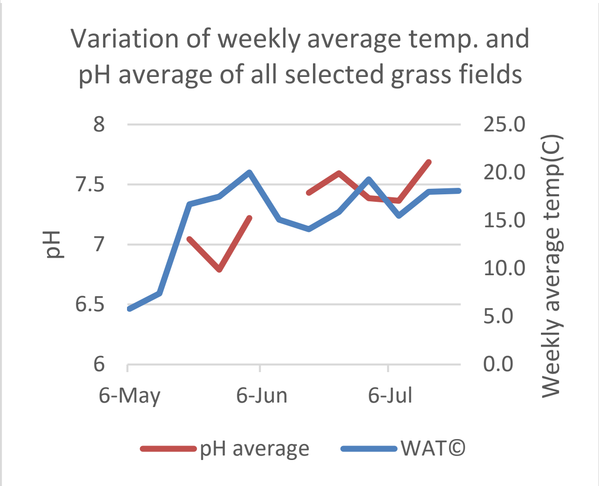


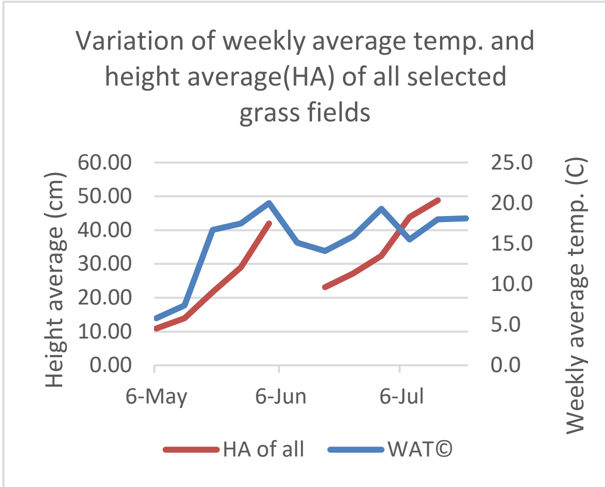


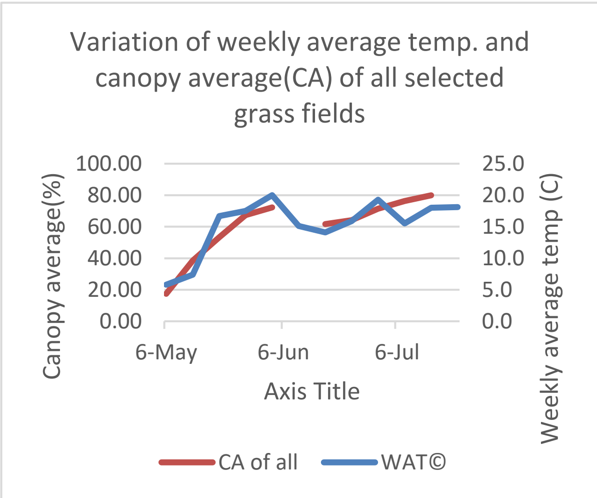


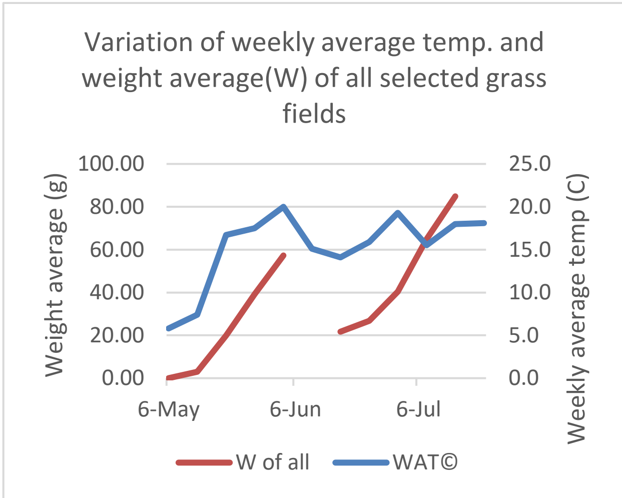
Appendix 3. Variation of weekly average temperature (WAT) with the growth factors of grass data taken as the average of all grass fields.

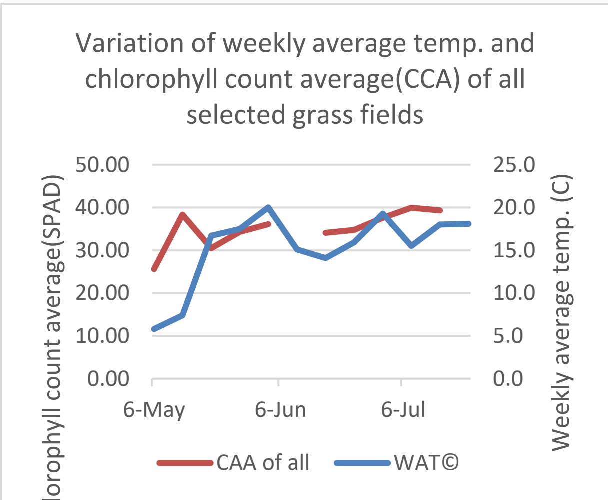
Graph 5 Variation of weekly average temperature (WAT) with the growth factors of grass data taken as the average of all grass fields in 2024





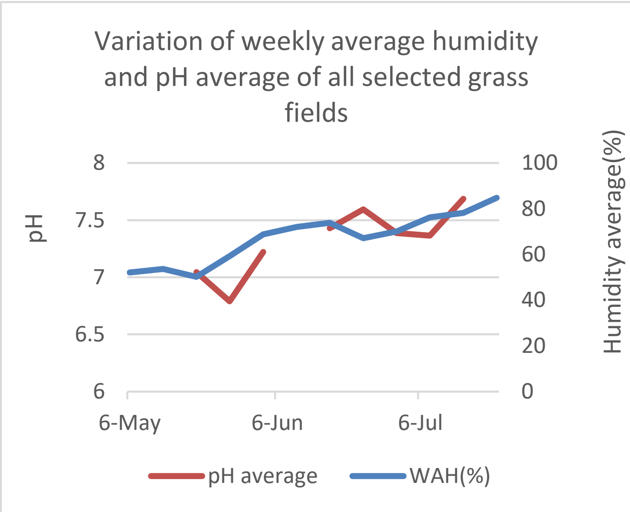


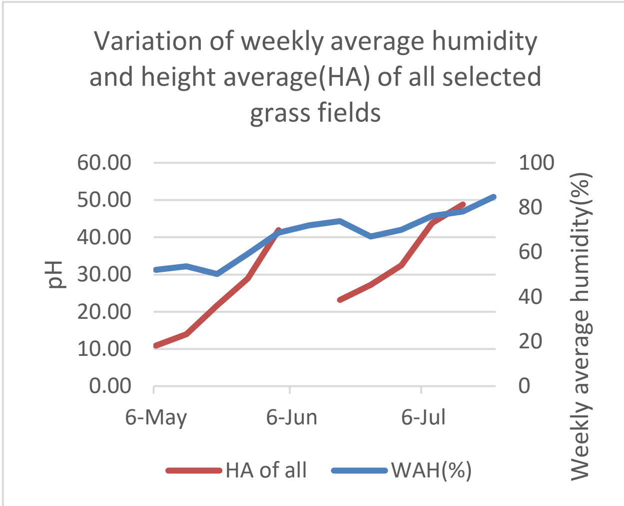


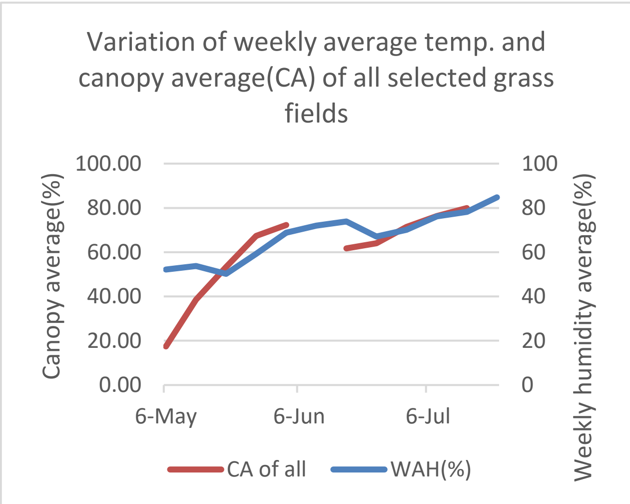


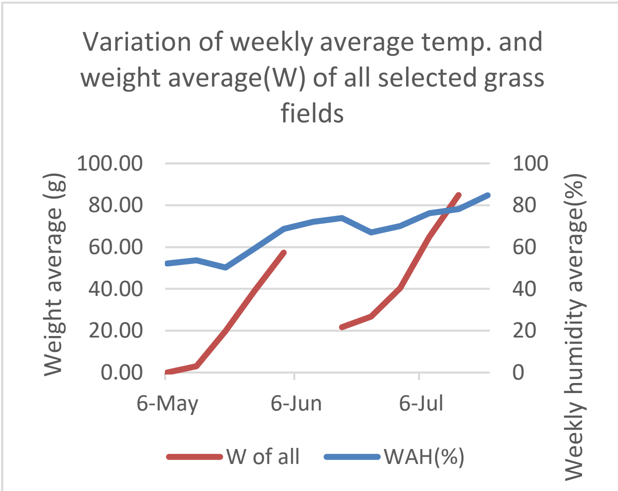
Appendix 4. Variation of weekly average humidity (WAH) with the growth factors of grass data taken as the average of all grass fields.

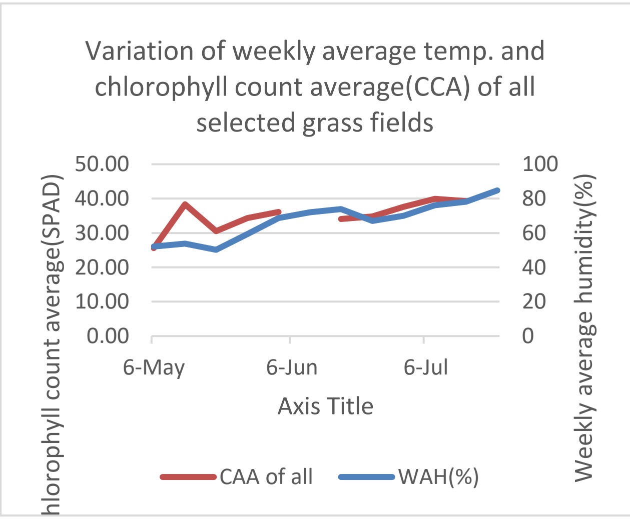
Graph 6 Variation of weekly average humidity (WAH) with the growth factors of grass data taken as the average of all grass fields in 2024.











Annex 5. Variation of weekly average humidity (WAH) with the growth factors of grass data taken as the average of all grass fields.

Graph 7 Variation of weekly average humidity (WAH) with the growth factors of grass data taken as the average of all grass fields in 2024.